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Effects of Increased Commercial Navigation Traffic on Freshwater Mussels in the Upper Mississippi River: 1992 Studies

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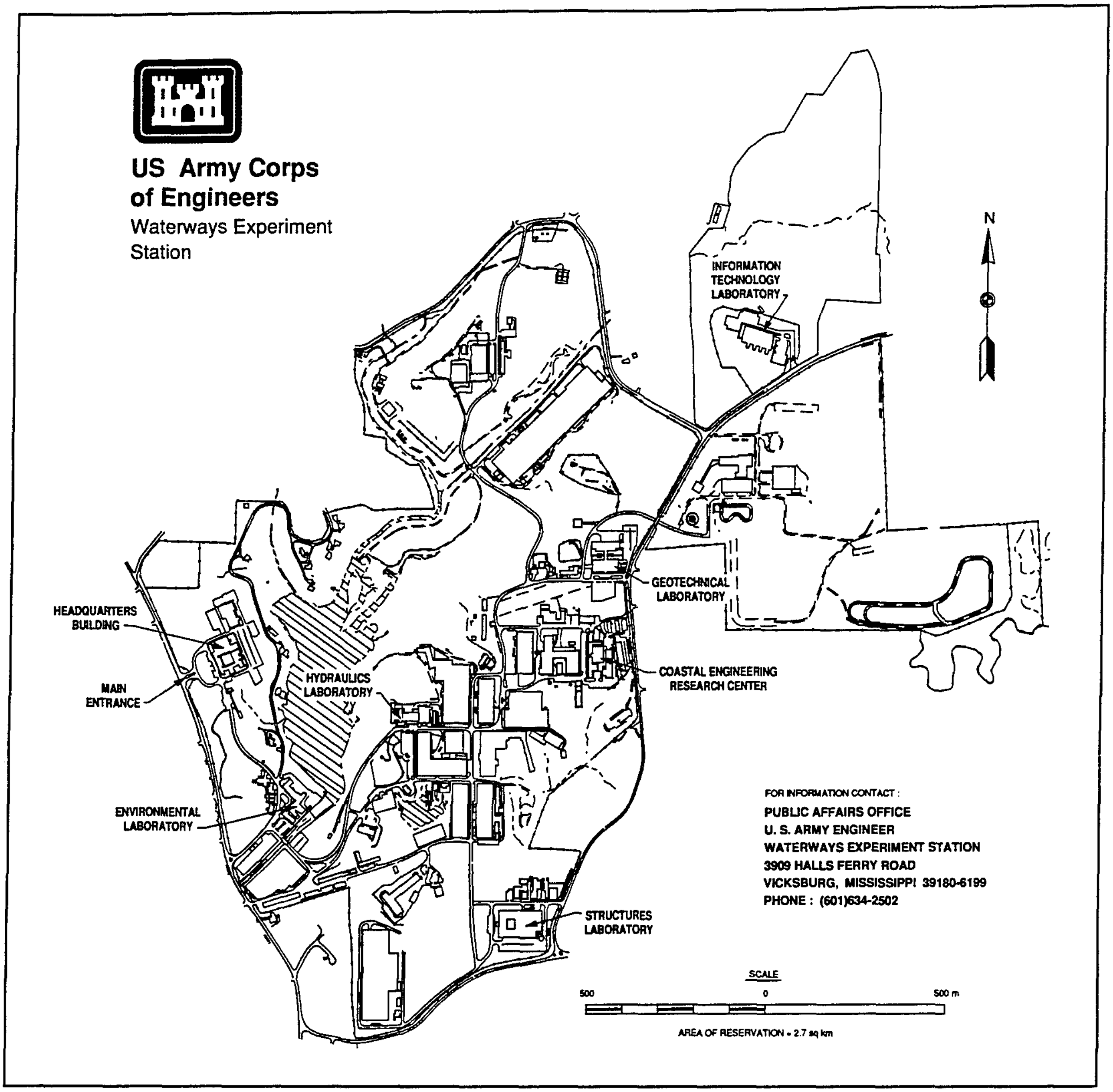

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Contents

Preface

In accordance with the Endangered Species Act, Section 7, Consultation, personnel from the U.S. Army Engineer District, St. Louis, and the U.S. Fish and Wildlife Service (USFWS) determined that a monitoring program should be initiated in the upper Mississippi River to assess the effects of existing and projected future increased traffic levels on freshwater mussels including the endangered Higgins eye mussel *Lampsilis higginsi*. Concern had been expressed by the USFWS and other agencies that projected increases in commercial traffic resulting from completion of the Melvin Price Locks and Dam, Second Lock Project (formally known as Locks and Dam 26) at Alton, IL, could negatively affect freshwater mussels. In 1988, the St. Louis District contracted with the U.S. Army Engineer Waterways Experiment Station (WES) to initiate these studies. The purpose of the 1988 studies was to identify sample sites for future work. This report describes results of the fourth full study year, which took place in 1992.

Divers for this study were Messrs. Larry Neill, Robert Warden, Rob James, and Jeff Montgomery from the Tennessee Valley Authority. Messrs. Will Green and Steve Thomas and Dr. David Beckett, University of Southern Mississippi, Hattiesburg, MS, and Mr. Robert Read, Wisconsin Department of Natural Resources, assisted in the field. Ms. Deborah Shafer, WES, was the U.S. Army Corps of Engineers diving inspector for this work. Ms. Sarah Wilkerson, Jackson State University, Jackson, MS, prepared all figures except maps, and Ms. Erica Hubertz, University of West Florida, identified and measured mussels in the laboratory at WES. Comments on an early draft of this report were provided by Mr. Dan Ragland, St. Louis District.

During the conduct of these studies, Dr. John Harrison was Director, Environmental Laboratory (EL), WES, Dr. Conrad J. Kirby was Chief, Ecological Research Division, EL, and Dr. Edwin A. Theriot was Chief of the Aquatic Ecology Branch, EL. Authors of this report were Drs. Andrew C. Miller and Barry S. Payne, Aquatic Ecology Branch, WES.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
inches	2.54	centimeters
miles (U.S. statute)	1.609347	kilometers

1 Introduction

Background

Operation of the second lock at the Melvin Price Locks and Dam (formerly the Locks and Dam 26 (Replacement) project) will increase the capacity for commercial navigation traffic in the upper Mississippi River (UMR). Changes in water velocity at the substratum-water interface and sediment scour as a result of propeller wash from commercial navigation traffic could detrimentally affect freshwater mussels (Mollusca: Unionidae), including *Lampsilis higginsi*, listed as Endangered by the U.S. Fish and Wildlife Service (USFWS) (1991). In accordance with the Endangered Species Act, Section 7, Consultation, personnel from the U.S. Army Engineer District (USAED), St. Louis, and the USFWS determined that a monitoring program should be initiated to assess the effects of projected traffic levels on freshwater mussels including *L. higginsi*. Other agencies that participated in the development of this program included the U.S. Army Engineer Divisions, Lower Mississippi Valley and North Central; USAED's, St. Paul and Rock Island; and state conservation agencies and other interested individuals.

A reconnaissance survey to choose sample sites and to conduct preliminary sampling was conducted in 1988 (Miller et al. 1990) and also in 1989 (Miller and Payne 1991). Detailed quantitative and qualitative studies at selected mussel beds were initiated in 1989 and will continue at least through 1994 to obtain baseline data. This report contains an analysis of data collected in July 1992, the fourth full year of the monitoring program.

Study Design

This research was designed to obtain information on changes in water velocity and suspended solids near the substratum-water interface when vessels pass dense and diverse mussel beds in the UMR. As part of these physical studies, important biotic parameters (species richness, species diversity, density, growth rate, and population structure of dominant mussel species) are being monitored. Physical and biological data are being collected at a farshore (experimental) and nearshore (reference) site within each mussel bed. Experimental sites are located near to the navigation channel (affected by vessel passage), and reference sites are located as far as possible from the channel (affected to a lesser extent by vessel passage). This research will couple empirical data from physical and biological studies to make predictions of the effects of vessel passage on freshwater mussels.

The objective is to determine whether commercial navigation traffic is negatively affecting *L. higginsi.* This is being accomplished by collecting information on all species of bivalves. As appropriate, results will be applied to *L. higginsi.* This surrogate species concept is being used since it is extremely difficult to obtain information on density, recruitment, etc., for uncommon species such as *L. higginsi.* In addition, intensive collecting of this species would be detrimental to its continued existence. The following six parameters, considered to be indicative of the health of a mussel bed, are being used to determine if movement of commercial navigation vessels is negatively affecting freshwater mussels.

a. Decrease in density of five common-to-abundant species.

b. Presence of *L. higginsi* (if within its range).

c. Live-to-recently-dead ratios for dominant species.

d. Loss of more than 25 percent of the species.

e. Evidence of recent recruitment.

f. A significant change in growth rates or mortality of dominant species.

Selected studies are being done at each bed each year of this monitoring project. Quantitative techniques are being used to collect mussels at each bed every second year. Each year qualitative methods are being used to collect mussels and search for endangered species. In addition, assessments of shell growth of dominant species are being done each year.

These data are being collected yearly during a period when traffic levels are not expected to increase. Sometime after 1994, biological and physical data will be collected at each bed once every 5 years. This will be done until traffic levels have increased as a result of completion of the Melvin Price Locks and Dam by an average of one tow per day above 1990 levels in the pool where monitoring takes place. Studies will then resume at the original rate (annually) and continue until 2040, the economic life of the project. Results of studies from each year are being reviewed annually to determine the need for altering sampling protocol. A schedule of studies to be conducted at each mussel bed appears in Table 1. A more complete description of this project appears in Miller et al. (1990). Results of the 1989 studies are in Miller and Payne (1991), results of the 1990 studies are in Miller and Payne (1992), and results of the 1991 studies are in Miller and Payne (1993).

Purpose and Scope

The purpose of this monitoring program (1988-94) is to obtain baseline data on physical (water velocity and suspended solids) and biological conditions (density, species richness, relative species abundance, population demography of dominant species, etc.) at five mussel beds between river miles (RM) 299 and 635 in the UMR.

2 Study Area and Methods

Study Area

The UMR was once a free-flowing, braided, pool-riffle habitat with side channels, sloughs, and abandoned channels. This riverine habitat was altered as a result of passage of the Rivers and Harbors Act of 3 July 1930, which authorized the U.S. Army Corps of Engineers to construct a navigation channel with a minimum depth of 9 ft and a minimum width of 300 ft.[1] Development of this navigation channel, which included construction of locks, dams, wing dams, and levees, converted the river to a series of run-of-the-river reservoirs, characterized by relatively slow-moving water and extensive adjacent lentic habitats. Typically, the upper reaches of pools in the UMR have comparatively high water velocity and coarse substratum, whereas the lower reaches are more lake-like with deep, low-velocity water and fine-grained sediments (Eckblad 1986).

Study Sites

In 1988, preliminary data on physical and biological conditions were collected at mussel beds in Pools 26, 25, 24, 19, 18, 17, 14, 10, and 7. In 1989, additional preliminary studies were conducted in Pools 12 and 13. Both qualitative and quantitative sampling techniques were employed to determine if the mussel bed identified by consulting resource maps (Peterson 1984) was suitable for detailed study. Based on information from these surveys, a list of mussel beds suitable for more detailed study was prepared. Personnel of the St. Louis District, U.S. Army Engineer Waterways Experiment Station (WES), and USFWS participated in the final selection process. Beds chosen for detailed study are located at the following river miles (Figure 1):

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1 A table of factors for converting non-SI units of measurement to SI units is presented on page vii.

Pool	RM
24	299.6 RDB
17	450.4 RDB
14	504.8 LDB
12	571.5 RDB
10	635.2 RDB (Main Channel)

Each bed is at least 1 mile long; exact locations on the bed often varies slightly from year to year. A brief description of each mussel bed follows.

Pool 24

This mussel bed is located on the right descending bank (RDB) approximately 1.5 miles downriver of Lock and Dam 22 (Figure 2). A series of wing dams on the left descending bank (LDB) direct water across the channel and toward the mussel bed. Commercial traffic must move along the RDB when approaching or exiting Lock and Dam 22. Substratum at this location consists of slab rock, coarse gravel, and sand. Although *L. higginsi* has never been found in Pool 24, this bed contains a dense and diverse assemblage of mussels. This location was included in this project so that representative data would be collected in the lower portion of the UMR. In 1992, 12 samples were collected using qualitative methods, and 10 total substratum samples (20-ℓ buckets filled with sediment) were collected. A summary of samples collected in previous years appears in Table 2.

Pool 17

The site in Pool 17 is on the RDB at RM 450.4 (Figure 3). Quantitative samples were first collected here in 1988 (Table 2). The substratum is fine-grained material with little gravel and some detritus. There are commercial loading facilities immediately upriver and downriver of this bed. In 1992, 60 quantitative and 24 qualitative samples were collected (Table 3).

Pool 14

An extensive mussel bed is located in the lower reach of Pool 14 on the LDB (Figure 4). Substratum consists of silt, sand, and gravel. This bed supports a dense and diverse assemblage of mussels, including *L. higginsi*. A summary of samples collected in previous years appears in Table 2. In this study year, 24 qualitative samples and 40 bucket samples were collected (Table 3).

Pool 12

The site in Pool 12 is located at RM 571.5 on the RDB (Figure 5). A summary of samples collected in previous years appears in Table 2. The mussel bed is long and narrow and located on the RDB of the river immediately downriver of a sharp left turn (coming downriver). Commercial vessels moving either upriver or downriver must approach the RDB (where the mussel bed is located) as they enter or exit the turn. In 1992, 60 quantitative and 36 qualitative samples were collected.

Pool 10

Near Prairie du Chien, WI, the UMR splits into an east and west or main channel (Figure 6). The east channel is slightly less deep and not as wide as the main channel, although during high water, it is navigable. Sediments in both the east and main channel consist of sand and silt with less than 5 percent gravel by weight. Numerous sloughs, aquatic plant beds, and islands characterize this river reach. The study site for this monitoring program is in the west or main channel of the UMR.

Physical Conditions at Each Mussel Bed

Grain-size distribution of sediments at mussel beds in Pools 24-12 are similar (Figure 7). Sediments in Pool 10 are dominated by particles less than 2.00 mm in diameter. These sediments are more similar to those in a backwater lake of Pool 10 than in the lower river. Organic content of sediments is similar at beds in Pools 24-12. Values at these beds are less than 50 percent the organic content of sediments in Pool 10 and approximately 1/10 the organic content in sediments in a backwater lake in Pool 10.

Data on gage height and total discharge has been obtained from locks either upriver or downriver of each site. During July, water levels were lower in 1988 and 1989 than in 1990 through 1992 (Figure 8). In 1992, gage height and total discharge tended to elevate during the month of July, although in 1990 and 1991, water levels were on the decline.

Methods

Preliminary reconnaissance

A diver equipped with surface air supply and communication equipment made a preliminary survey of each sample site before detailed studies of mussels began. He obtained information on substrate type, water velocity, and presence of mussels. A fathometer was used to measure water depth, and distance to shore was determined with an optical range finder.

Qualitative collections

Qualitative samples were obtained by two divers working simultaneously. The pair of divers was given a total of 12 nylon bags and instructed to place about 5 mussels in 3 bags and then about 20 mussels in the remaining 9 bags. Divers attempted to collect only live mussels, although occasionally dead shells were taken that had to be discarded. Collecting was done mainly by feel since water visibility was poor. Mussels were brought to surface, identified, and counted. Selected mussels were shucked and retained for voucher. Additional specimens were preserved in 10-percent buffered Formalin and returned to the laboratory for analysis of physical condition (ratios of shell length to tissue dry mass, etc.). Unneeded mussels were returned to the river unharmed.

Quantitative sampling

At each site, ten 0.25-m^2 quadrat samples were obtained at each of three subsites separated by 5 to 10 m. At each subsite, quadrats were placed approximately 1 m apart and arranged in a 2 by 5 matrix. A diver removed all sand, gravel, shells, and live molluscs within the quadrat. It usually took 5 to 10 min to clear the quadrat to a depth of 10 to 15 cm. All material was sent to the surface in a 20-ℓ bucket, taken to shore, and sieved through a nested screen series (finest screen with apertures of 6.4 mm) and picked for live organisms. All bivalves were identified, and total shell length (SL) measured to the nearest 0.1 mm. All *L. higginsi* were returned to the river unharmed. Some of the bivalves were measured in the evening, then returned to the river the next day. Bivalves that could not be processed were preserved in 10-percent buffered Formalin and taken to WES for analysis. Notes were made on the number of "fresh dead mussels" (defined as dead individuals with tissue still attached to the valves).

Nonquantitative, total substratum samples

At mussel beds where samples were not collected using quantitative methods (RM 299.6, 504.8, and 635.2, main channel), divers filled a specific number of 20-ℓ buckets with substratum. Buckets were transported to shore, sediments were sieved, and live mussels removed. Bivalves from all buckets were combined, identified, and counted. Because mussels were collected without size bias, these data were used to analyze demography and evidence of recruitment. Data from these collections cannot be used to estimate density. This sampling procedure has not been used in the past. It was initiated in 1992 to obtain information on size demography at beds where quantitative methods would not be used.

Physical effects of vessel passage

In 1989, 1990, and 1991, the effects of vessel passage on water velocity were analyzed using Marsh McBirney current meters. Data were also collected on the effects of vessel passage on changes in total suspended solids concentration or turbidity. During the 1992 study year, additional data were collected on the effects of vessel passage on turbidity. A station was established by anchoring a buoy approximately 300 ft from shore. A flexible garden hose was secured to a block, dropped to the bottom, and the hose was then secured to the buoy. A diver inspected the hose to be sure that it was appropriately positioned near the substratum water interface. When a commercial vessel approached, two individuals took a small boat out to the buoy and attached a battery-operated pump to the hose. Water samples were taken near the substratum-water interface with the pump and at the surface by hand. Water samples were taken every 60 sec starting about 5 to 10 min before the vessel passed and for about 5 to 10 min after the vessel passed. Turbidity was measured on shore with a Hach turbidimeter.

Growth studies

In 1990, growth studies were initiated at mussel beds in Pool 14, Pool 17, Pool 12, and Pool 10. Demographically complete groups of dominant unionid species were collected, total SL was measured in the field, and each specimen was engraved with an identifying code using a dremel tool. At each site, three 0.25-m^2 aluminum quadrats were cabled together with 20 m of 3/8-in. coated wire rope. The quadrats were secured to the river bottom, and all substrate (i.e., live bivalves, sand, and gravel) was excavated to a depth of 10 to 15 cm. Twenty liters of screened gravel and the marked mussels were placed in each quadrat.

In subsequent years, these sites were revisited and quadrats were retrieved. Mussels were measured and yearly growth rates computed. In addition to directly measuring growth by this technique, growth of dominant species was estimated by analysis of length frequency histograms and by measuring all interannular distances on previously collected mussels.

Data analysis

All bivalve data (lengths, weights, etc.) were entered on a spreadsheet and stored in ASCII files. Summary statistics were calculated using functions in the spreadsheets or with programs written in BASIC or Statistical Analysis System (SAS). All computations were accomplished with an IBM or compatible XT or AT personal computer. Biological and physical data were plotted directly from ASCII files using a Macintosh SE computer and laser printer.

3 The Bivalve Community

Qualitative Techniques

A total of 25 species of bivalves and 1,724 individuals were collected with 120 samples taken using qualitative methods at five beds in the UMR (Table 4). *Amblema plicata plicata* comprised nearly 40 percent of the fauna and was taken in 85 percent of the samples. Thirteen species comprised 10 to 1 percent, and eleven species comprised less than 1 percent of the fauna. Fourteen species were collected in more than 10 percent of the samples. Percent abundance and frequency of occurrence at each pool appear in Appendix A.

Excluding *A. p. plicata*, the entire assemblage was evenly distributed with all species spanning just more than three orders of magnitude (Figure 9). Species rank versus percent abundance and percent occurrence appear in Figure 10. *Amblema plicata plicata* became increasingly more dominant in the upper as compared with the lower part of the Mississippi River, resulting in disproportionately high abundances of this first dominant species at UMR Mile 571.5 and especially at UMR Mile 635.2 (Figure 10).

The relationship between cumulative number of species collected versus cumulative number of individuals collected can be used to illustrate the difficulty of finding uncommon species. At RM 450.4, the species area curve leveled off after approximately 200 individuals and 19 species had been collected (Figure 11). After approximately 400 individuals had been collected at RM 504.8, 571.5, and 635.2, at least 20 species had been collected. An examination of curves for all of the mussel beds studied illustrates that additional effort would have yielded some additional (although uncommon) species.

Quantitative Techniques

Density

Quantitative methods were used to collect bivalves at RM 450.4 and 571.5 during the 1992 survey year. At RM 450.4, the overall mean density (± standard error of the mean, SE) at the nearshore site (76.4 ±4.6 individuals/square meter) was significantly greater ($P > 0.05$) than at the farshore site (50.8 $\pm$5.7 individuals/square meter, Table 5, Figure 12). At RM 572.5, mean mussel densities were not significantly different among sites ($P > 0.05$) (Table 6, Figure 13). Typically, nearshore sites, where the scouring effects of moderate to high current velocity is reduced, have higher densities than sites closer to the channel.

Community characteristics

Based on quantitative sampling, there were no substantial differences in the pattern of distribution of species within the community at nearshore versus farshore sites at mussel beds at RM 450.4 or 571.5 (Figures 13 and 14). A list of species collected using quantitative methods can be found in Appendix B.

At RM 450.4, the relationship between cumulative number of species identified versus cumulative number of individuals collected using qualitative methods was similar at the nearshore and farshore sites (Figure 15). Twenty-two species were found at the nearshore site and nineteen were collected at the farshore site. The additional effort required to collect 381 individuals at the farshore site did not yield an additional species (see Figure 3, bottom). At RM 571.5, 18 species were identified after 230 individuals were collected at the nearshore site (Figure 16). No additional species were identified at the midshore site after 129 more individuals were collected. Collecting 199 more individuals at the farshore site yielded three additional species.

In 1992, divers collected total substratum (bucket samples without the 0.25-sq m quadrat) at mussel beds where quantitative samples would not be collected. Data from these samples were used to evaluate demography, species diversity, and dominance (Table 7). Data collected using this method and with the 0.25-sq m quadrats were used to evaluate changes in percent abundance of dominant species versus river mile. For example, *Ellipsaria lineolata* comprised a greater percentage of the assemblage in the lower river (RM 299.6 and 450.4) than at the three mussel beds located farther upriver (Figure 17). *Truncilla truncata* showed no specific trend with respect to river mile or distance to shore (Figure 5). Conversely, both *A. p. plicata* and *Fusconaia flava* tended to form a larger component of the bivalve assemblage at upriver beds (Figure 18).

Species diversity (H') ranged from slightly more than 1.5 to about 2.5 at all five mussel beds (Figure 19). Dominance, which ranges from near 0 for evenly distributed communities to near 1 for assemblages strongly dominated by one species, was greatest at RM 635.2 (Figure 19). Higher values for dominance at this location were the result of the high percentage of *A. p. plicata* in Pool 10 (also see Table 7 and Figure 10).

Evidence of recent recruitment, either in terms of percent individuals or species less than 30 mm total SL, was variable among the mussel beds studied and exhibited no specific trend with respect to river mile (Figure 20). The bed at RM 299.6 showed good evidence of recent recruitment at the nearshore site (see section on demography, below). Typically, from approximately 10 to 40 percent of the individuals were less than 30 mm total SL, and 30 to 60 percent of the species had at least one individual less than 30 mm total SL (Figure 20).

Evidence of recent mortality

As the quantitative samples were processed, the number of fresh dead bivalves (individuals that were obviously dead but still had tissue attached to the valves) were counted (Table 8). No fresh dead mussels were found at RM 450.4, although one was taken at RM 571.5.

Presence of *Lampsilis higginsi*

Based on qualitative sampling methods, *L. higginsi,* listed as endangered by the USFWS (1991), comprised 0.78 percent (three individuals) at RM 504.8, and 0.27 percent (one individual) at RM 635.2 (Table 9). Using quantitative methods at RM 504.8, 571.5, and 635.2, this species comprised 0.25, 0.18, and 0.43 percent of the assemblage, respectively. In 20 buckets of sediment at a nearshore site at RM 635.2, three *L. higginsi* (1 percent) were collected (Table 7). During this study, *L. higginsi* has not been found at the mussel bed in RM 229.6 and is rarely taken at RM 450.4.

Demographic Analysis

Size demography of dominant populations in each pool

Populations sampled in sufficient numbers to inspect demography did not show any nearshore versus farshore differences. Therefore, demography was considered for the combined results of sampling at nearshore and farshore sites. Provided below is a brief description of the size structure of dominant populations at each bed. Site and species-specific frequency histograms of shell length are provided in Appendix C.

Size demography of dominant mussels in Pool 24

Three species were collected in sufficient numbers to analyze population size structure. These included relatively small individuals of a species that grow to large adult size (*A. p. plicata*), all size and age classes of a species that grow to moderately small (*O. reflexa*), and one species that is small as an adult (*T. truncata*). No large mussels were collected at this bed.

Amblema plicata plicata. A sample of 21 individuals revealed a population heavily dominated by small mussels (Figure C1). Recent recruits measuring between 28 and 50 mm in length comprised 95 percent of the sample. The largest mussels obtained measured 59 mm, although *A. p. plicata* commonly grows to approximately 100 mm in length.

Obliquaria reflexa. This species grows to moderately small adult size in comparison to *A. p. plicata.* Because of the paucity of large mussels in Pool 24, the demography of *O. reflexa* was apparently similar to that of *A. p. plicata.* All *O. reflexa* obtained were between 10 and 50 mm long. Although sample size was too low for reliable analysis, it appeared that four cohorts were present: the smallest with modal length of 10 to 14 mm; the next largest ranging from 16 to 26 mm; the third ranging from 30 to 38 mm; and a fourth ranging from 40 to 50 mm (Figure C2).

Truncilla truncata. This species is among the more diminutive unionids. The maximum length of 50 mm observed is typical. Length ranged from 16 to 50 mm, although all but 4 of 27 mussels collected measured between 34 and 50 mm (Figure C3).

Size demography of dominant mussels in Pool 17

Ten species were collected in sufficient abundance to inspect demography. Most populations showed complex size and age structure, indicating relatively consistent annual recruitment. This aspect of the mussel bed in Pool 17 was also reflected by the taxonomic composition of abundant species. Included were long-lived species that grow to massive adult size (e.g., *M. nervosa* and *A. p. plicata*), species of intermediate size and longevity (e.g., *Quadrula* spp.), and small species with a short life span (e.g., *T. truncata* and *Truncilla donaciformis*). Species-specific descriptions of demography are provided in approximately the order of adult size and longevity (largest to smallest as adults).

Megalonaias nervosa. A total of 33 individuals were obtained, with all but 5 measuring between 78 and 122 mm in length (Figure C4). The smallest mussel measured 26 mm; the largest measured 152 mm.

Amblema plicata plicata. This was the most abundant species; a total of 175 individuals were obtained from quantitative samples. Sizes and ages spanned the entire range expected for *A. p. plicata* (Figure C5). The smallest mussel measured 18 mm and the largest 100 mm. Approximately 55 percent of the population was less than the median size of 59 mm. Although cohort structure could not be clearly discerned, it is likely that approximately 5-year classes were represented by individuals ranging from 18 to 59 mm in length. Size-specific abundance peaked at 24 to 32 mm among these young cohorts. Among older mussels greater than 59 mm, size-specific abundance peaked at 72 to 84 mm. The relative paucity of mussels ranging from 48 to 66 mm probably represents relatively weak recruitment years. The decline in abundance of mussels greater than 84 mm probably reflects natural mortality or commercial harvesting affects, or both.

Ellipsaria lineolata. All sizes and ages were represented among 130 individuals representing this population (Figure C6). The smallest mussels measuring 20 to 26 mm almost certainly represent 1991 recruitment. Other possible cohorts were obvious peaks in relative abundance at 38 to 50 mm, 56 to 64 mm, and at 72 to 74 mm.

Quadrula quadrula. Only 27 individuals were obtained from this population, yet all size and age classes were present (Figure C7). The smallest mussel measured 12 mm and the largest measured 72 mm.

Quadrula metanevra. A small sample (23 individuals) precluded detailed analysis of size structure. In this sample, there was no evidence of very recent recruitment; the smallest mussel obtained was 44 mm long (Figure C8). The sample was comprised mostly of moderate to moderately large individuals (44 to 72 mm).

Quadrula pustulosa. *Quadrula pustulosa* was the most abundant species of *Quadrula* collected at this mussel bed (n = 213). Its size demography included all sizes and ages, and there was abundant evidence of strong recent recruitment (Figure C9). Total size range was 8 to 62 mm. Small mussels (<30 mm long) comprised approximately 55 percent of the population. There was evidence of year classes centered at 18 to 20 mm, 24 to 30 mm, 36 to 40 mm, 42 to 46 mm, 48 to 54 mm, and 56 to 60 mm.

Obovaria olivaria. A small sample (n = 25) of this species included both recently recruited individuals and moderately large adults. The four mussels ranging from 18 to 24 mm represent either 1991 or 1990 recruitment. The remaining 21 mussels in this sample ranged from 42 to 64 mm in length. The upper limit approximates the maximum expected length of this mussel in the UMR.

Obliquaria reflexa. This population included individuals of all age and size classes (Figure C10). Minimum length was 14 mm and maximum length was 54 mm. Most of the population fell into two closely adjacent cohorts centered at 28 to 32 mm and at 34 to 38 mm. An additional cohort ranged from 40 to 48 mm in length.

Truncilla truncata. A large sample (n = 167) of this population included what appeared to be three major cohorts (Figure C11). The modal length of the smallest was 16 to 18 mm. Presumably, this cohort represents 1991 recruitment. The next largest cohort (1990 recruits) had modal length of 28 to 32 mm. The third major cohort (1989 recruits) had modal length of 38 to 42 mm. A possible fourth minor cohort was centered at 46 to 48 mm; these mussels may represent a few individuals of the 1988 cohort that survived into a fourth year.

Truncilla donaciformis. A sample of 30 individuals of this especially small mussel included only a single clear cohort that ranged from 16 to 26 mm in length (Figure C12). A single mussel measuring 11 mm in length was also collected.

Size demography of dominant mussels in Pool 14

Species collected in sufficient abundance for demographic analysis from Pool 14 were a subset of the dominants collected in Pool 17. Population demography was generally similar, with most populations including individuals of most possible size and age classes. However, the relative abundance of recent recruits was somewhat less in Pool 14 than in Pool 17.

Megalonaias nervosa. Most individuals collected from this population were of intermediate to large size (Figure C13). Thirty-seven of thirty-nine individuals obtained from quantitative samples ranged from 68 to 156 mm. Two very young recruits (1991 cohort) were obtained that measured 20 to 24 mm in length.

Amblema plicata plicata. Individuals ranged from 12 to 104 mm long (Figure C14). Virtually all size classes less than 58 mm (population median length) were represented. The relative abundance of mussels below the median length was 38 percent.

Ellipsaria lineolata. This species was collected in moderate abundance only in Pools 17 and 14. Demography was strikingly similar at the two locations. In Pool 14, the smallest *E. lineolata* measured 20 mm long and the largest individual was 80 mm long (Figure C15). Mussels ranging from 18 to 26 mm almost certainly represent 1991 recruits.

Quadrula quadrula. The size range of this species in Pool 14 (Figure C16) was similar to that in Pool 17. Individuals ranged from 12 to 86 mm. Medium and large *Q. quadrula* were abundant. All but 8 of 66 individuals collected were greater than 48 mm in length.

Quadrula pustulosa pustulosa. Like *Q. quadrula*, the size range of *Q. p. pustulosa* was similar in Pool 14 (Figure C17) and Pool 17. Individuals ranged from 10 to 68 mm. However, large *Q. p. pustulosa* were of higher relative abundance in Pool 14. Mussels greater than 40 mm comprised 68 percent of the population in Pool 14 and only 32 percent of the population in Pool 17.

Obovaria olivaria. Demography of this species was virtually identical in Pool 14 (Figure C18) and Pool 17. The 1991 year class was represented by mussels ranging from 18 to 24 mm. All remaining individuals ranged from 42 to 72 mm in length. Despite relatively small sample sizes, the lack of mussels between 26 and 42 mm probably indicates weak recruitment of this species in 1990.

Obliquaria reflexa. The smallest individual measured 12 mm and the largest measured 54 mm (Figure C19). Relative abundance of large *O. reflexa* was high. Mussels greater than 40 mm long comprised 67 percent of the population.

Truncilla truncata. This population was represented by all size and age classes (Figure C20). Individuals ranged from 10 to 48 mm and probably fell into three major cohorts. The 1991 year class was represented by mussels ranging from 10 to 22 mm. The 1990 year class was twice as abundant as 1991 recruits and was represented by mussels of modal size 24 to 34 mm. The modal size of the 1989 year class, which was three times more abundant than the 1990 year class, ranged in modal length from 36 to 44 mm.

Size demography of dominant mussels in Pool 12

Four species were collected in sufficient numbers at the mussel bed in Pool 12 for demographic analysis. In Pools 14 and 17, virtually all size and age classes were represented by dominant populations.

Amblema plicata plicata. Length ranged from 14 to 102 mm (Figure C21). This population was marked by relatively consistent annual recruitment. Recent cohorts less than the population median length of 58 mm comprised 58 percent of the sample. The 1990 year class, centered at 22 to 24 mm, was approximately twice as abundant as the 1991 year class (centered at 14 to 16 mm) or several adjacent year classes of the late 1980s (ranging from 32 to 58 mm long). Only 11 percent of the population exceeded 74 mm.

Quadrula quadrula. Size structure of this population was similar in Pool 12 (Figure C22) and Pool 14. In Pool 12, individuals ranged from 10 to 86 mm in length. Mussels ranging from 10 to 14 mm represented 1991 recruits. Most of the population (75 percent) was greater than 48 mm long.

Obliquaria reflexa. This population was dominated by mussels ranging from 26 to 48 mm in length that probably fell into two closely adjacent cohorts (Figure C23). The most abundant cohort of *O. reflexa* ranged from 34 to 48 mm in length.

Truncilla truncata. This population included a full range of sizes and ages; mussels ranged from 14 to 48 mm (Figure C24). Intermediate-sized *T. truncata* had high relative abundance; mussels ranging from 20 to 38 mm (presumably representing 1990 recruitment) comprised approximately 68 percent of this population.

Size demography of dominant mussels in Pool 10

Five species were collected in sufficient numbers at the mussel bed in Pool 10 for demographic analysis. As in Pools 12, 14, and 17, dominant populations included virtually all age and size classes, indicating sustained recruitment to these populations.

Megalonaias nervosa. Demography of this population (Figure C25) was similar to that in Pools 12, 14, and 17 except that no very small *M. nervosa*, representing 1991 recruits, were included in this sample. *Megalonaias nervosa* ranged from 58 to 148 mm long, a size range virtually identical to that of abundant individuals in the other pools. Only a single small mussel (27 mm) and two small individuals (20 to 24 mm) represented 1991 recruitment in Pools 17 and 12, respectively.

Amblema plicata plicata. Once again, this population showed evidence of relatively consistent annual recruitment (Figure C26). Young cohorts centered at 16 to 18 mm, 22 to 26 mm, 40 to 44 mm, and 48 to 54 mm probably represented 1991, 1990, 1988, and 1987 year classes, respectively. The 1989 year class was probably represented by the broad shoulder 28 to 34 mm in the upper end of the size distribution of the more abundant 1990 year class. Thirty-nine percent of the population was less than the median length of 54 mm.

Fusconaia flava. Even a small sample of this population (n = 23) was sufficient to indicate relatively consistent annual recruitment. All size and age classes were represented (Figure C27). The smallest *F. flava* measured 14 mm and the longest 80 mm. There was indication of highest relative abundance of mussels 32 to 50 mm in length.

Obliquaria reflexa. Individuals ranged from 20 to 58 mm in length (Figure C28). Although sample size was small (n = 30), it appeared that approximately four cohorts made up this population. The smallest mussels, measuring 20 to 26 mm, probably represented 1991 recruitment.

Truncilla truncata. This population appeared to consist of three major cohorts (Figure C29). The smallest was centered 12 to 18 mm (1991 recruits). The next largest was centered at 26 to 32 mm (1990 recruits). A third cohort (1989) was centered at 34 to 44 mm in length. The few mussels ranging upward from 46 mm in length could indicate that some individuals survive to be 4 years old.

Interpool comparisons of commonly abundant species

Three species, *A. p. plicata, O. reflexa*, and *T. truncata*, were collected in sufficient numbers for demographic analysis of populations in all pools. *Truncilla truncata* is a species that attains small adult size and lives for approximately 3 years. *Obliquaria reflexa* grows to moderately small adult size and has longevity of about 5 years. *Amblema plicata plicata* grows to relatively massive adult size and has longevity of approximately 15 to 20 years. Thus, the size and age structure of *A. p. plicata* populations provide insight into ecological conditions that extend back nearly 2 decades. In contrast, the populations of the two smaller species reflect a more brief period of recent history.

Amblema plicata plicata. Interpool comparisons of the size structure of the most abundant unionid in the upper Mississippi River revealed considerable similarity among Pools 17, 14, 12, and 10, but stark contrast between conditions at these locations and Pool 24. The population in Pool 24 was heavily dominated by moderately small *A. p. plicata;* populations in the other pools were comprised of a relatively equal mix of all size classes (Figure 21). In Pools 17, 14, 12, and 10, maximum length of *A. p. plicata* ranged only from 94 mm (at RM 635.2) to 102 mm (at RM 504.8), and minimum length ranged only from 12 mm (at RM 505) to 18 mm (at RM 450.4). All four populations of *A. p. plicata* showed evidence of strong recent recruitment, with consecutive year classes accounting for individuals ranging from the minimum to approximately the median size class observed in each population. The entire sample of *A. p. plicata* in Pool 24 measured less than 60 mm in length, and nearly all individuals were between 30 and 60 mm long. The Pool 24 population was comprised almost entirely of a single year class of relatively recent recruits.

Since 1989, this single cohort has been the dominant feature of the demography of the Pool 24 population (Figure 22). When first sampled in 1989, *A. p. plicata* at RM 299.6 consisted of a single cohort (probably 1988 recruits) with average length of 14 mm. When sampled again in 1991, this dominant cohort had grown to an average length of 32 mm. An average individual in this cohort had grown to 42 mm by 1992. The larger sample sizes of 1989 and 1991 relative to 1992 probably accounts for the inclusion of a greater range of size classes in the earlier 2 years. Based on growth of the 1988 cohort, it appears that length increase is linear from the first through fourth year of life. Annual growth averages 9 mm.

By combining length-frequency data on *A p. plicata* from Pools 17, 14, 12, and 10 (i.e., those showing similar demography), it was possible to achieve an extremely large sample size (n = 886) that, in turn, made it possible to individually discern closely adjacent cohorts of recent recruits (Figure 23). Assignment of age classes to these young cohorts identified in length-frequency histogram closely matched estimates of age-length relationships from measurements of length at distinct shell annuli (Figure 24). Shell annuli could be accurately counted on young, small mussels (<60 mm long). Based on data summarized in Figure 23, strength of annual recruitment followed the pattern 1990 >> 1989, 1988 > 1987, 1986 > 1991. Because of the high relative abundance of the 1990 year class, the next larger cohort of 1989 recruits is represented as a "shoulder" on the upper tail of the size-frequency distribution of the 1990 mussels in Figure 23. It is noteworthy that the average annual growth increment of 9 mm indicated by the growth model in Figure 24 equals growth observed for the 1988 cohort of *A. p. plicata* monitored in Pool 24 from 1989 through 1992 (Figure 22).

Pools 17, 14, 12, and 10 populations of *A. p. plicata* all included an abundance of mussels in larger size classes (i.e., those individuals ranging upwards in size from the recognizable recent recruitment cohorts). These larger mussels undoubtedly represent multiple, consecutive year classes. As mussels age, the cumulative effect of slowing growth rate and individual variability in growth rate make it increasingly difficult to discern cohorts in a length-frequency histogram. Adjacent cohorts become too overlapped to be individually discerned. Furthermore, shell annuli are increasingly difficult to recognize for the more recent years of growth of old, large mussels. Thus, year classes prior to 1986 are not identified in Figure 22. It is likely that the abundant mussels ranging from 62 to 86 mm in length are a combination of six or more cohorts. The decline in mussel abundance for individuals longer than 82 mm probably reflects natural mortality, although it is also true that commercial harvesting disproportionately removes large mussels and may contribute to the paucity of very large *A. p. plicata* in the UMR.

Obliquaria reflexa. Population size demography was much more similar among all pools (Figure 25) for this moderately small and short-lived species than for *A. p. plicata.* The minimum size collected ranged from 10 mm (Pool 24) to 20 mm (Pool 10); maximum size ranged from 48 mm (Pool 12) to 58 mm (Pool 10). Populations in all five pools included some individuals of most size classes, although relative abundance by size varied. For example, Pool 14 had substantially higher relative abundance of large *O. reflexa* than did the Pool 17 population.

A composite representation of all populations indicated three to five cohorts (Figure 26). The minor peak at 13 mm may not be "real" since it includes only three mussels, and both the minor peaks at 25 mm occurring in the lower shoulder of the major peak at 29 mm may be part of the same cohort. In addition, the broad upper shoulder of the peak centered at 41 mm suggests that a minor cohort may be hidden within the upper end of the size distribution associated with that peak. Thus, the longevity of *O. reflexa* averages between 3 and 6 years, depending on precisely how these cohorts are interpreted. An intermediate value of 4 or 5 years is likely to be an accurate estimate of the average longevity of *O. reflexa.*

Truncilla truncata. The size demography of populations of this small mussel varied somewhat among pools (Figure 27), but not to the extent that *A. p. plicata* demography varied. Populations in Pools 24 and 14 were characterized by having far more large than small *T. truncata.* Populations in Pools 12 and 10 were dominated by intermediate-sized *T. truncata.* The Pool 17 population had a relatively equal abundance of all size classes. A composite representation of all *T. truncata* in the UMR clearly suggested three cohorts (Figure 28). The smallest of these, centered at approximately 16 mm probably represents 1991 recruits. The next largest, centered at approximately 29 mm, represents 1990 recruits. The third and largest cohort, centered at 39 mm, represents 1989 recruits. This interpretation suggests an average longevity of greater than 3 years, but less than 4 years for this small unionid.

4 Physical Effects of Commercial Vessel Passage

Turbidity was measured before and after vessel passage at RM 571.5 during 1992 (Figures 29 and 30). Initial turbidity ranged from 38 Nephelometer Turbidity Units NTU (Event 2) to approximately 90 NTU (Event 5). Event 2 (Figure 29) exhibited only a very minor increase in turbidity following passage of the commercial vessel. Passage appeared to have little or no effects on ambient turbidity levels for the other six events. Changes in turbidity as a result of vessel passage was also measured at this site in 1990 (Miller and Payne 1992). Ambient turbidity was approximately 50 percent of values obtained in 1992. It is likely that the higher discharge, water levels, and ambient turbidity masked vessel-induced changes in 1992.

In a slough at RM 689.6 (Pool 8), the effects of upbound passage of two 21-ft skiffs on ambient turbidity was measured (Figure 31). Ambient turbidity (before the vessels passed) was approximately 10 NTU (five samples were collected at each time interval). The two vessels passed 260 sec and 460 sec after the start of the experiment, respectively. These vessels increased turbidity approximately six times (120 NTU) above ambient levels. The experiment was terminated after 600 sec and the turbidity had not returned to ambient conditions, although it had declined by more than 50 percent of maximum recorded levels.

5 Discussion

Examination of the Health of UMR Mussel Beds

The purpose of this monitoring program is to document important biotic attributes at prominent mussel beds in the UMR. This information will be used to document changes in biological and physical changes (if any) through time. Six attributes of mussel assemblages at these beds were identified that will be used to evaluate change. Physical effects studies, conducted at beds where biological data are collected, are being used for analysis of cause and effect. Although more biological data will be collected in future years, recently collected information can be used to analyze these beds. The purpose of the following section is to examine the six attributes of the mussel fauna at these beds using the data collected since 1988.

Decrease in density of five common-to-abundant species

For this attribute both density (individuals per square meter) as well as percent species abundance in an assemblage are being considered. At RM 450.4 and 571.5, mean densities since 1990 have varied but without a definite trend (Figures 32 and 33). Although data for more years would be needed to fully assess changes in the UMR, the information collected to date does not suggest that mussel stocks are declining.

The relative abundance of two common mussels, *A. p. plicata* and *T. truncata,* was evaluated for the period of this study. At RM 299.6, the percentage of *A. p. plicata* has increased since 1988, although the relative abundance of this species has remained about the same at three other mussel beds (Figure 34). In contrast to *A. p. plicata,* the relative abundance of *T. truncata* has declined at RM 299.6, although its abundances in the other mussel beds have remained about the same (Figure 35). No dramatic changes in density or relative species abundance have been noted based on the information collected in the past few years. It is likely that interyear variation, due mainly to the exact location of sample sites on the mussel bed, is due to chance variations. Changes in relative abundance of relatively short-lived species (for example *T. truncata*) are reasonable, especially since they probably did not successfully recruit in large numbers each year.

Presence of *L. higginsi* (if within its range)

In the main channel of the river in Pool 10 (RM 635.2), the percentage of *L. higginsi* in 1992 ranged from 0.23 to 0.68 percent in samples collected using quantitative methods and 0.0 to 1.72 percent in samples collected using qualitative methods (Table 9). Although numbers vary from year to year at beds in Pools 14, 12, and 10, there does not appear to be a specific trend either toward increased or decreased numbers of this species. This species has never been abundant in large rivers (Higgins' Eye Recovery Team 1982), and based on our data, its numbers do not appear to be changing.

Live-to-recently-dead ratios for dominant species

In quantitative samples taken in the UMR, often 50 percent or more of the shells can be considered "relics" and may have been dead for many years. One objective of this study is to quantify the number of "fresh dead" mussels taken in quantitative samples. These are defined as mussels that are dead but still have have tissue attached to the shells. Only a single fresh dead mussel was found in all of the quantitative samples collected at RM 450.4 and 571.5 in 1992 (Table 8). Although commercial shell fisherman and casual collectors have occasionally reported high numbers of fresh dead mussels at certain locations in the UMR, evidence of high mortality has not been observed in any of the samples of this study.

Loss of more than 25 percent of the mussel species

The number of species collected is directly related to the number of individuals collected; hence this attribute has to be viewed with some caution. At RM 450.4 in 1990, 27 species and over 1,000 individuals were collected. In 1992, 22 species and 954 individuals were collected using quantitative methods (Figure 36). At RM 571.5, a total of 22 species were collected in 1990 and 1992, respectively; interyear differences were slight.

Between 1988 and 1991, the number of species and individuals collected using qualitative methods at RM 299.6 was relatively constant (Figure 37). In 1992, only 184 individuals and 13 species were collected. The reduced number of species is not necessarily a cause for concern. In 1993, quantitative samples will be collected at this bed, which will provide the opportunity for obtaining more individuals and more species. At RM 504.8, the number of species collected between 1988 and 1992 has remained relatively constant and ranged from 18 to 21.

Species diversity (H'), which depends upon the number of species (richness) and the distribution of species within the community (evenness), can be used as a monitor of the overall health of a mussel bed. At the five mussel beds studied, species diversity ranged from less than 1.5 to nearly 2.5

(Figures 38 and 39). No specific increases or decreases through time of this parameter have been noted.

Evidence of recent recruitment

The percentage of individuals with a total shell length less than 30 mm and the percentage of species with at least one individual less than 30 mm shell length is being used as a measure of recent recruitment. The bed at RM 299.6 was characterized by comparatively high recent recruitment; the percent of individuals less than 30-mm SL has always been greater than 40 percent (Figure 40). At RM 450.4, considerably greater recruitment (about twice values reported for 1990 or at the farshore site in 1992) was found at the nearshore site. Community-wide recruitment appears to be declining slightly at RM 504.8 and possibly increasing at RM 635.3 (Figure 41). Additional data, to be collected in 1993 and 1994, can be used to provide additional information on the annual variation in recruitment at these beds.

A significant change in growth rates or mortality of dominant species

Size demography of *A. p. plicata* populations could indicate the health of mussel communities in the UMR pools. Interpool comparisons of *A. p. plicata* clearly showed that Pools 17, 14, 12, and 10 support considerably healthier populations of this species than did Pool 24. The upper four pools supported populations with relatively equal abundance of most size and age classes of *A. p. plicata* (Figure 21). In stark contrast, the Pool 24 population of *A. p. plicata* was heavily dominated by a single-year class (1988) of recruits.

For long-lived unionids such as *A. p. plicata,* reasonably consistent annual recruitment provides a continuous source of growing stock to replace old, large mussels lost to natural mortality or commercial harvest. Consistently strong annual recruitment not only contributes to sustainable yield of harvested mussels, but also indicates that in nearly all years physical and biological conditions are conducive to successful reproduction and recruitment. Therefore, healthy populations are those that are comprised of relatively equal numbers of all or most size and age classes. For large, long-lived mussels like *A. p. plicata,* populations that include a reasonably equal mix of all or most size and age classes (e.g., Pools 10, 12, 14, and 17 in Figure 21) are a clear indication of a thriving population. In general, where demography of *A. p. plicata* indicated a healthy population, the same indication was given by the size structure of large or moderately large and long-lived species (e.g., *M. nervosa, E. lineolata,* and *Quadrula* spp.) (Appendix C).

At the other extreme are populations either heavily dominated by old, senescent individuals that do not show evidence of recruitment or by small, recent recruits of single-year class or two. The former condition (not observed in any UMR populations reported on herein) indicates a population of potential reproductive value that occurs in a location rarely or no longer showing recruitment. The latter condition (observed in Pool 24) indicates possible recovery of a population at a location that only sporadically supports recruitment. The Pool 24 population of *A. p. plicata* is characterized by dominance of single-year class—1988 recruits. This cohort has grown at a rate of 9 mm per year, equal to that of young *A. p. plicata* in Pools 17, 14, 12, and 10. The similar rate of growth indicates that once recruited, conditions are suitable for survival and growth of *A. p. plicata.* Recruitment success appears to be a limiting factor for mussels in Pool 24. Continued long-term monitoring of this community should indicate if the mussel bed is generally improving or if infrequent recruitment is simply a characteristic of this site.

Interpool differences in *A. p. plicata* population demography were striking and provide important insight into the health of these populations. In contrast, interpool differences in *O. reflexa* and *T. truncata* populations were much less apparent. The latter two species are both very short lived compared with *A. p. plicata.* Thus, analysis of size demography of long-lived species that grow to massive adult size appears to be most useful for evaluating the condition of mussel beds.

Summary

The pulse of velocity and turbulence associated with passage of commercial vessels is usually considered to be their major detrimental environmental impact. It has been suggested that vessel-induced change in magnitude and direction of flow negatively affects benthic organisms by scouring substrates and resuspending fine-grained sediments (Rasmussen 1983). Tolerances of many aquatic organisms to sustained, specific levels of turbulence, water velocity, or suspended solids is known either from laboratory or field studies. Intermittent disturbances caused by vessel movement, pulses of suspended sediments, changes in water velocity, and periods of desiccation, can be simulated in the laboratory. Navigation-related studies have been conducted on fish eggs (Morgan et al. 1976), fish larvae (Killgore, Miller, Conley 1987; Holland 1986; Payne, Killgore, and Miller 1991), plankton (Stevenson et al. 1986), and freshwater mussels (Aldridge, Payne, Miller 1987; Payne and Miller 1987). Results of most studies demonstrated that mortality or physiological stress could be measured under conditions corresponding to high traffic intensity. In the field, discharge, flow patterns, bathymetry, and sediment characteristics have complex influences on vessel-induced disturbances. It is extremely difficult to estimate an organismal response to these intermittent physical effects, and it is even more difficult to accurately predict long-term responses of natural populations to such disturbances. Results of the few navigation-related field studies that have been conducted are characterized by extreme spatial and temporal variability so that clear patterns of navigation effects often cannot be discerned (Sparks, Thomas, and Schaeffer 1980; Bhowmik et al. 1981a, 1981b; Seagle and Zumwalt 1981; Eckblad 1981; Eckblad, Volden, Weilgart 1984; Environmental Science and Engineering 1981, 1988; Holland 1986). In addition, natural climatic and hydrologic conditions often overwhelm navigation effects (Johnson 1976).

An examination of the six attributes of a mussel bed that define its health or well-being were made based on studies conducted in the UMR since 1989. In most cases, only 3 full years of comparison can be made. Regardless, an examination of these six attributes, based on information collected to date, reveals that they are stable at these mussel beds. However, future studies will be used to determine if important indices such as rate of growth, density, species richness and diversity, etc., are changing. These biotic data sets are strengthened by the physical studies. A detailed examination of physical effects of traffic at the sites where biological information is being collected is necessary to thoroughly evaluate effects of commercial traffic. Planners and resource managers are encouraged to make careful evaluations using these data, rather than speculation based on "best estimates" or qualitative assessments such as habitat-based methods.

References

Aldridge, D., Payne, B. S., and Miller, A. C. (1987). "The effects of intermittent exposure to suspended solids and turbulence on three species of freshwater mussels," *Environmental Pollution* 45, 17-28.

Bhowmik, N. G., Adams, J. R., Bonini, A. P., Guo, C-Y, Kisser, D., and Sexton, M. (1981a). "Resuspension and lateral movement of sediment by tow traffic on the Upper Mississippi and Illinois Rivers. Illinois State Water Survey Division," SWS Contract Report 269, Environmental Work Team, Upper Mississippi River Basin Commission Master Plan Task Force, Minneapolis, MN.

Bhowmik, N. G., Lee, M. T., Bogner, W. C., and Fitzpatrick, W. (1981b). "The effects of Illinois River traffic on water and sediment input to a side channel," Illinois State Water Survey Contract Report 270, Environmental Work Team, Upper Mississippi River Basin Commission Master Plan, Minneapolis, MN.

Eckblad, J. W. (1981). "Baseline studies and impacts of navigation on the benthos, drift, and quantity of flow to side channels and the suspended matter entering side channels of Pool 9 of the Upper Mississippi River," Report prepared for the Environmental Work Team of the Upper Mississippi River Basin Committee, Minneapolis, MN.

__________. (1986). "The ecology of Pools 11-13 of the Upper Mississippi River: A community profile," U.S. Fish and Wildlife Service, Biological Report 85 (7.8), 90.

Eckblad, J. W., Volden, C. S., and Weilgart, L. S. (1984). "Allochthonous drift from a backwater to the main channel of the Mississippi River," *American Midland Naturalist* 11(1), 16-22.

Environmental Science and Engineering, Inc. (1981). "Navigation impact study, Illinois and Mississippi Rivers," Phase III, Task 9, Gainesville, FL.

__________. (1988). "Final report, 1987 Ohio River Ecological Research Program," St. Louis, MO.

Higgins' Eye Mussel Recovery Team. (1982). "Higgins' Eye Recovery Plan," report submitted to the U.S. Fish and Wildlife Service.

Holland, L. E. (1986). "Effects of barge traffic on distribution and survival of Ichthyoplankton and small fishes in the upper Mississippi River," *Transactions of the American Fisheries Society* 115, 162-165.

Johnson, J. H. (1976). "Effects of tow traffic on resuspension of sediments and dissolved oxygen concentration in the Illinois and Upper Mississippi Rivers under normal flow conditions," Technical Report Y-76-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Killgore, K. J., Miller, A. C., and Conley, K. C. (1987). "Effects of turbulence on yolk-sac larvae of paddlefish," *Transactions of the American Fisheries Society* 116, 670-673.

Miller, A. C., Payne, B. S., Hornbach, D. J., and Ragland, D. V. (1990). "Physical effects of increased commercial navigation traffic on freshwater mussels in the Upper Mississippi River: Phase I studies," Technical Report EL-90-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Miller, A. C., and Payne, B. S. (1991). "Effects of increased commercial navigation traffic on freshwater mussels in the Upper Mississippi River: 1989 studies," Technical Report EL-91-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

__________. (1992). "The effects of commercial navigation traffic on freshwater mussels in the Upper Mississippi River: 1990 studies," Technical Report EL-92-23, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

__________. (1993). "The effects of commercial navigation traffic on freshwater mussels in the Upper Mississippi River: 1991 studies," Technical Report EL-93-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Morgan, R. P., Ulanowicz, R. E., Rasin, V. J., Noe, L. A., and Gray, G. B. (1976). "Effects of shear on eggs and larvae of Striped Bass, *Morone saxatilis*, and White Perch, *Morone americana*," *Transactions of the American Fisheries Society* 106, 149-154.

Payne, B. S., Killgore, K. J., and Miller, A. C. (1991). "Mortality of yolk-sac larvae of paddlefish entrained in high-velocity water currents," *Journal of the Mississippi Academy of Sciences* 35, 7-9.

Payne, B. S., and Miller, A. C. (1987). "Effects of current velocity on the freshwater bivalve *Fusconaia ebena*," *Bulletin of the American Malacological Union* 5, 177-179.

Peterson, G. A. (1984). "Resources inventory for the Upper Mississippi River (Guttenber, Iowa to Saverton, Missouri)," Prepared for the U.S. Army Engineer District, Rock Island, Rock Island, IL.

Rasmussen, J. L. (1983). "A summary of known navigation effects and a priority list of data gaps for the biological effects of navigation on the Upper Mississippi River," Prepared for the U.S. Army Engineer District, Rock Island, by the U.S. Fish and Wildlife Service, Contract No. NCR-LO-83-C9, Rock Island, IL.

Seagle, H. H., and Zumwalt, F. H. (1981). "Evaluation of the effects of tow passage on aquatic macroinvertebrate drift in Pool 26, Mississippi River," Upper Mississippi River Basin Commission, Minneapolis, MN.

Sparks, R. E., Thomas, R. C., and Schaeffer, D. J. (1980). "The effects of barge traffic on suspended sediment and turbidity in the Illinois River," Completion Report to U.S. Fish and Wildlife Service, Rock Island, IL.

Stevenson, R. J., Mollow, J. M., Peterson, C. G., and Lewis, J. L. (1986). "Laboratory simulation of navigation traffic physical effects on river Plankton," report submitted to U.S. Army Engineer District, Louisville, Contract DACW27-85-R-0043, Louisville, KY.

U.S. Fish and Wildlife Service. (1991). "Endangered and threatened wildlife and plants," 50 CFR 17.11 & 17.12 (April 10, 1987), Office of Endangered Species, U.S. Fish and Wildlife Service, Washington DC.

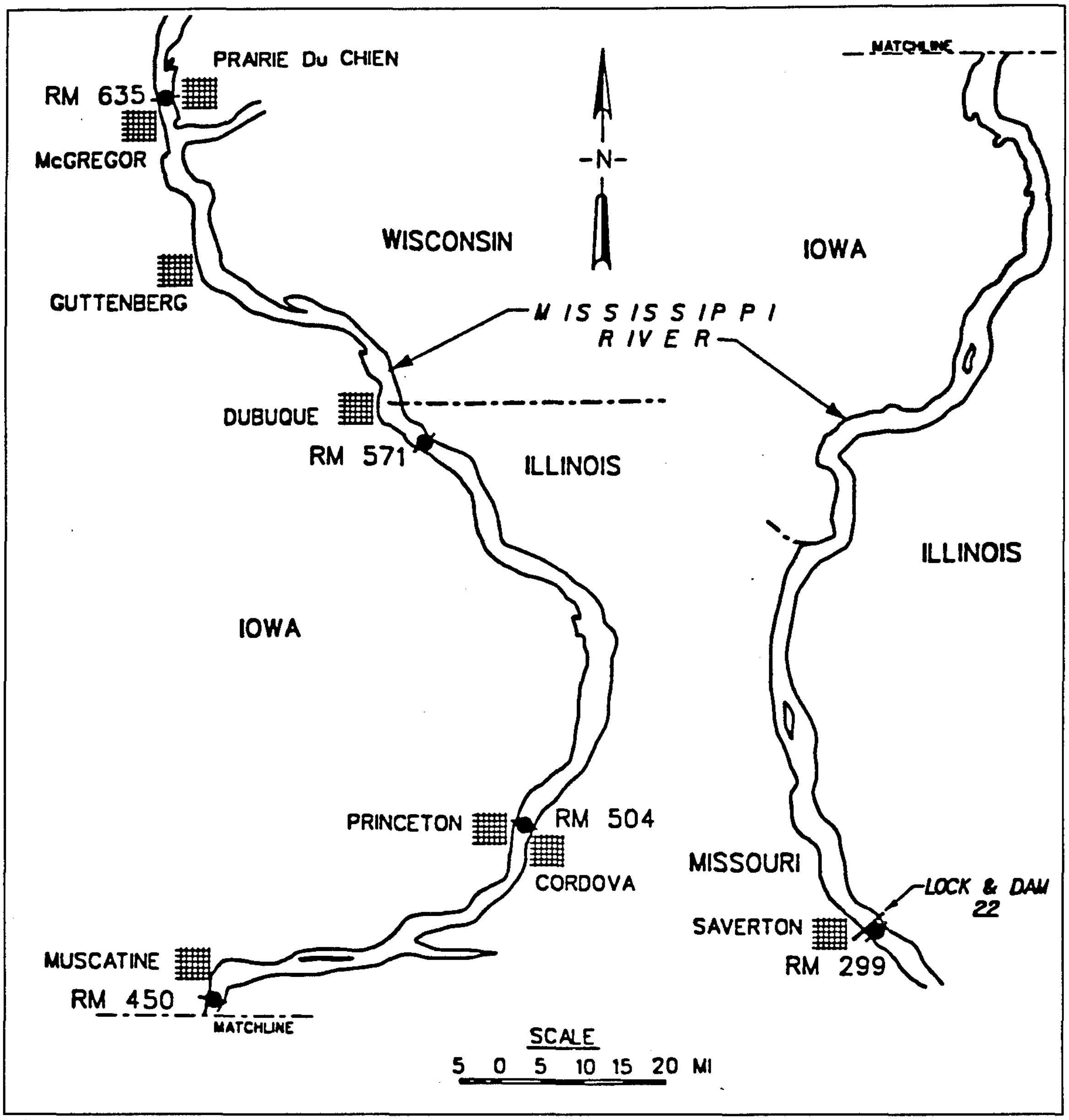


Figure 1. Location of the five mussel beds chosen for detailed study in the UMR, 1989-1994

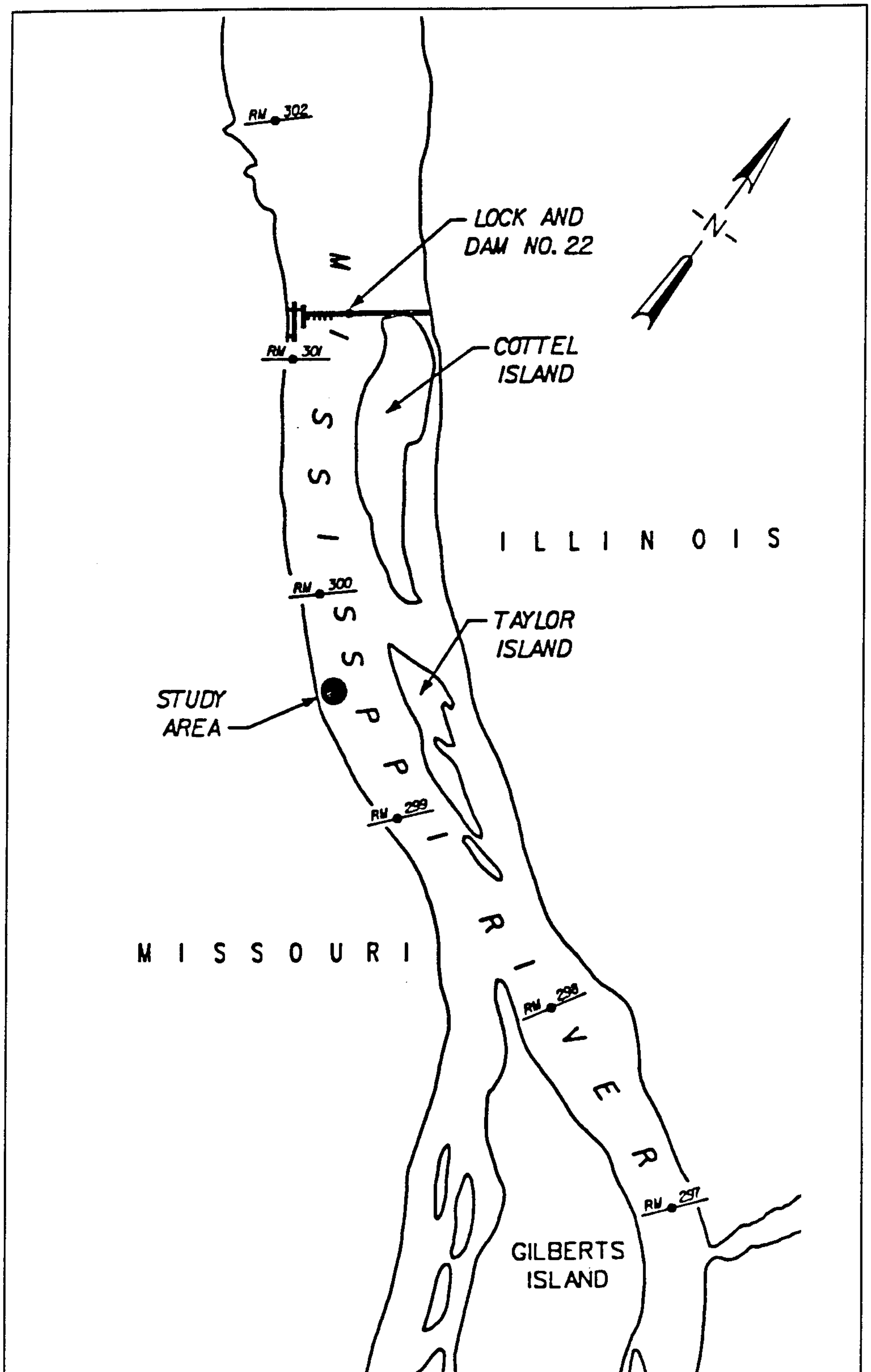


Figure 2. Study area at the mussel bed located in Pool 24, RM 299.6

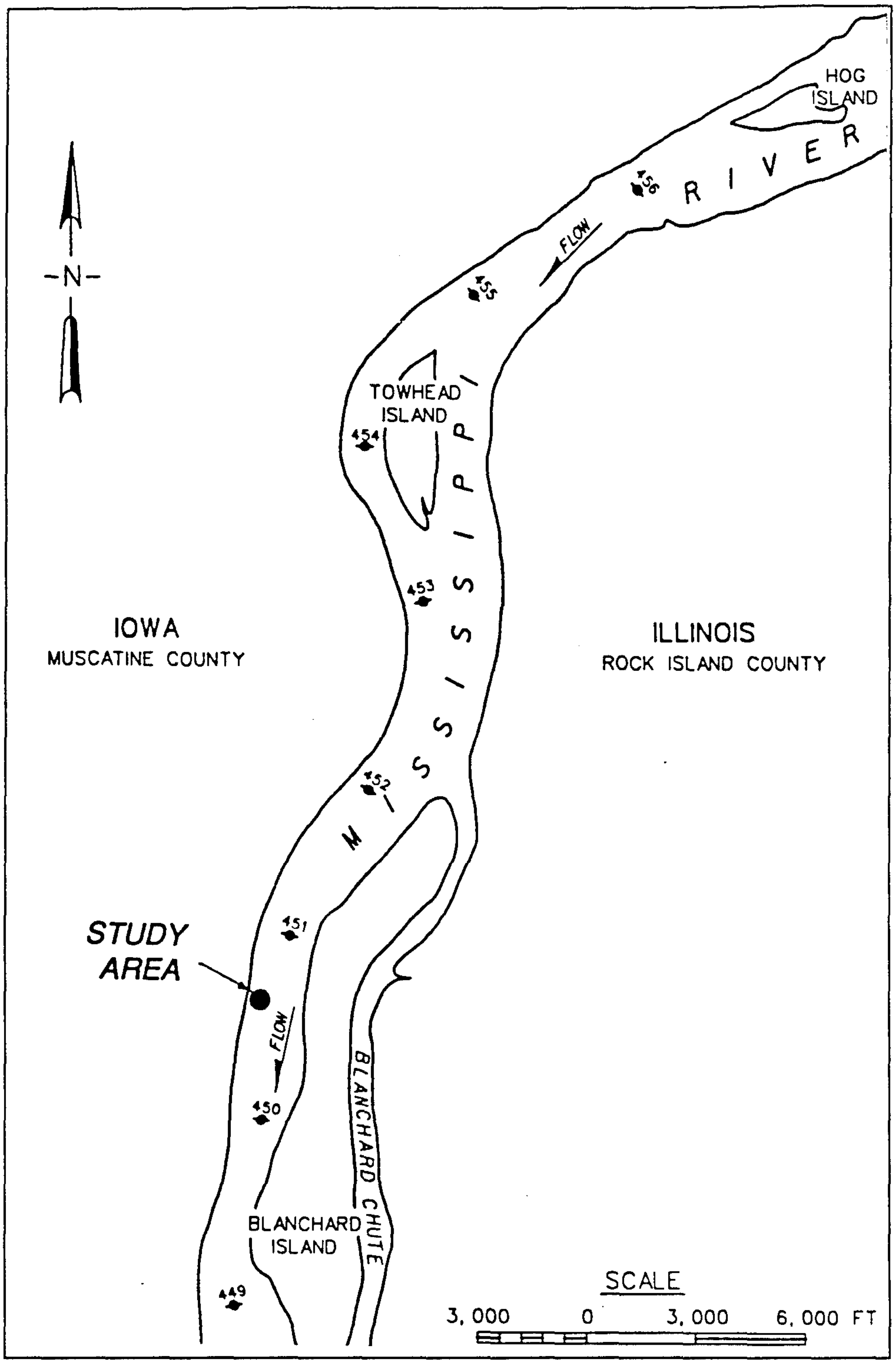


Figure 3. Study area at the mussel bed located in Pool 17, RM 450.4

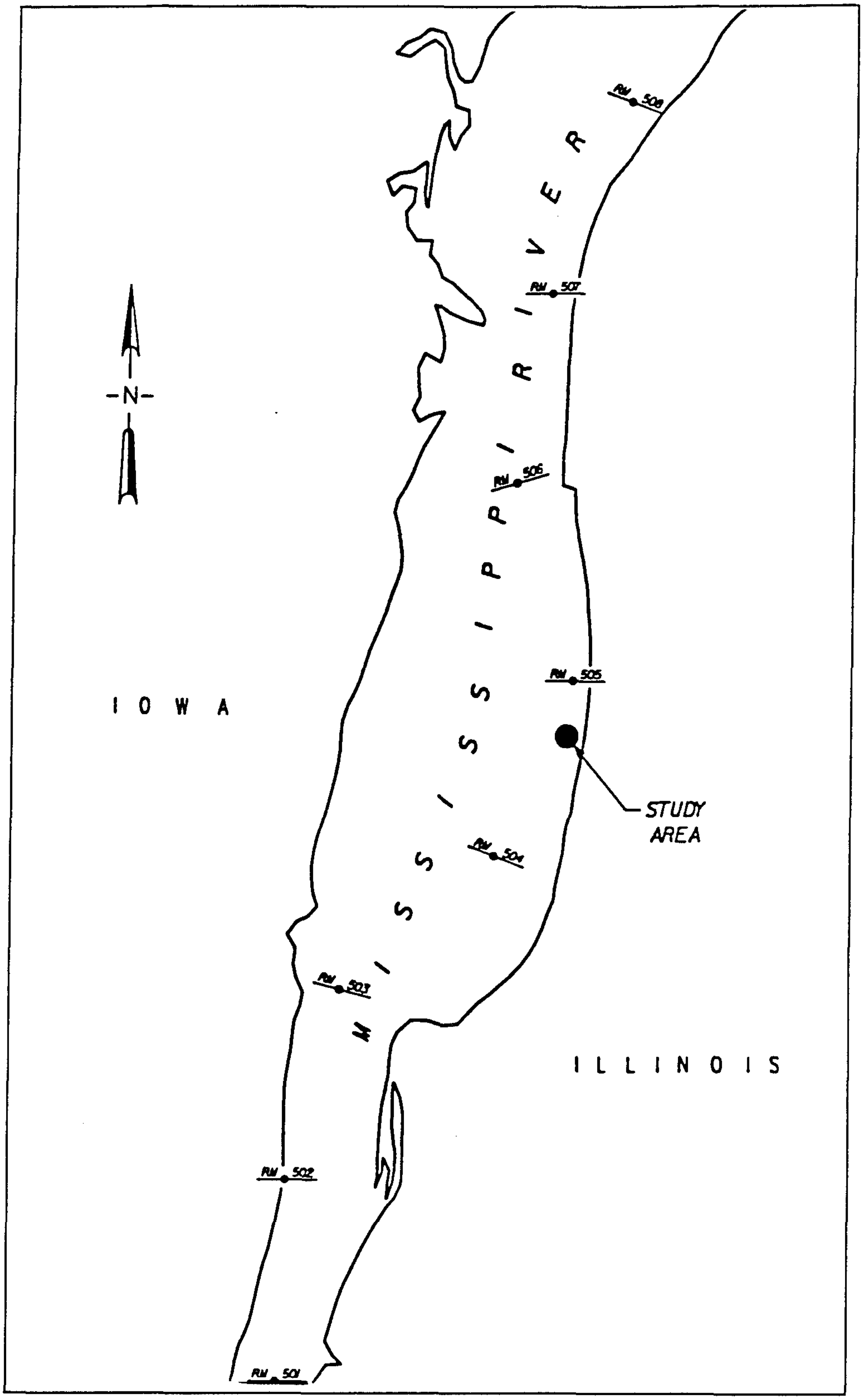


Figure 4. Study area at the mussel bed located in Pool 14, RM 504.8

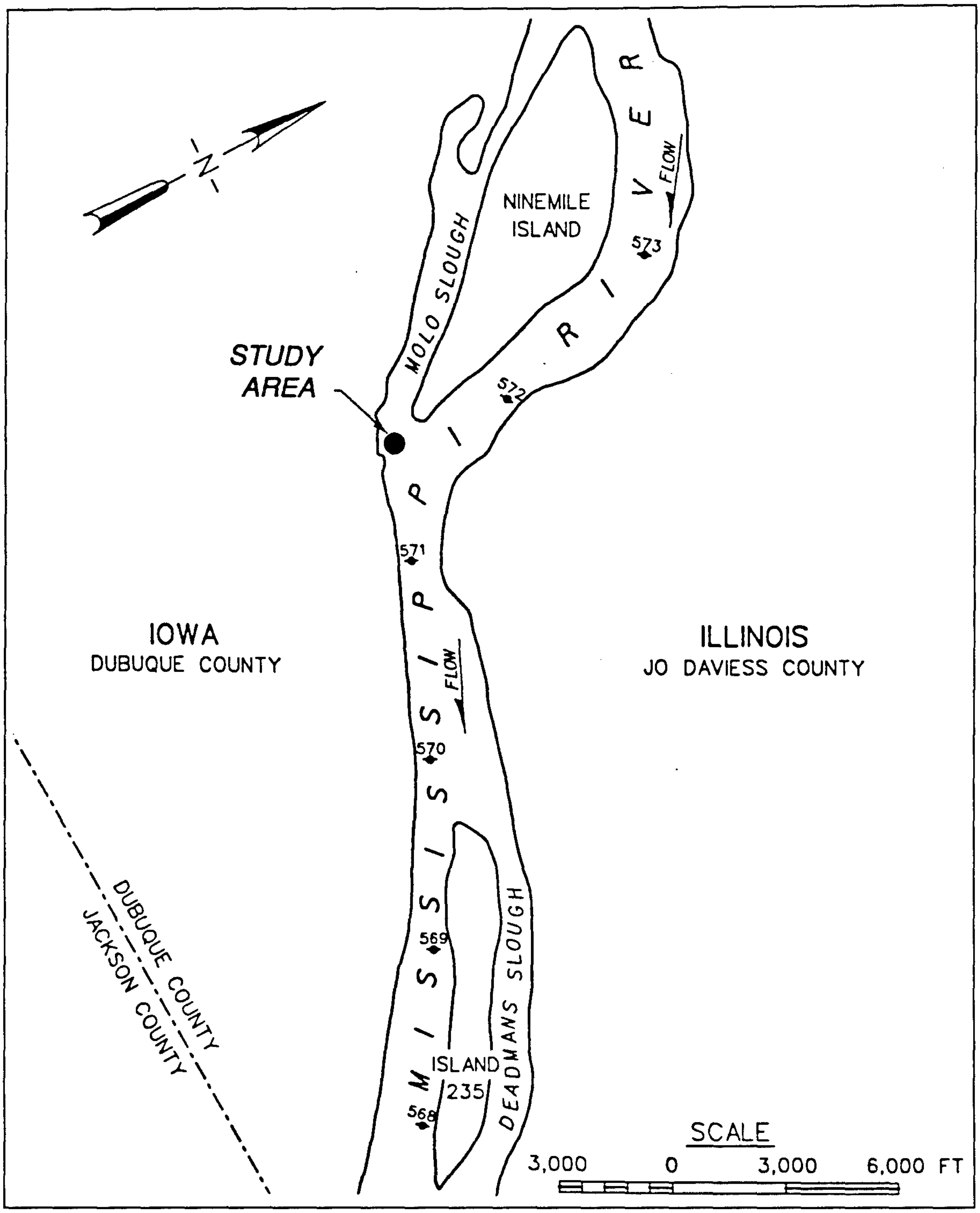


Figure 5. Study area at the mussel bed located in Pool 12, RM 571.5

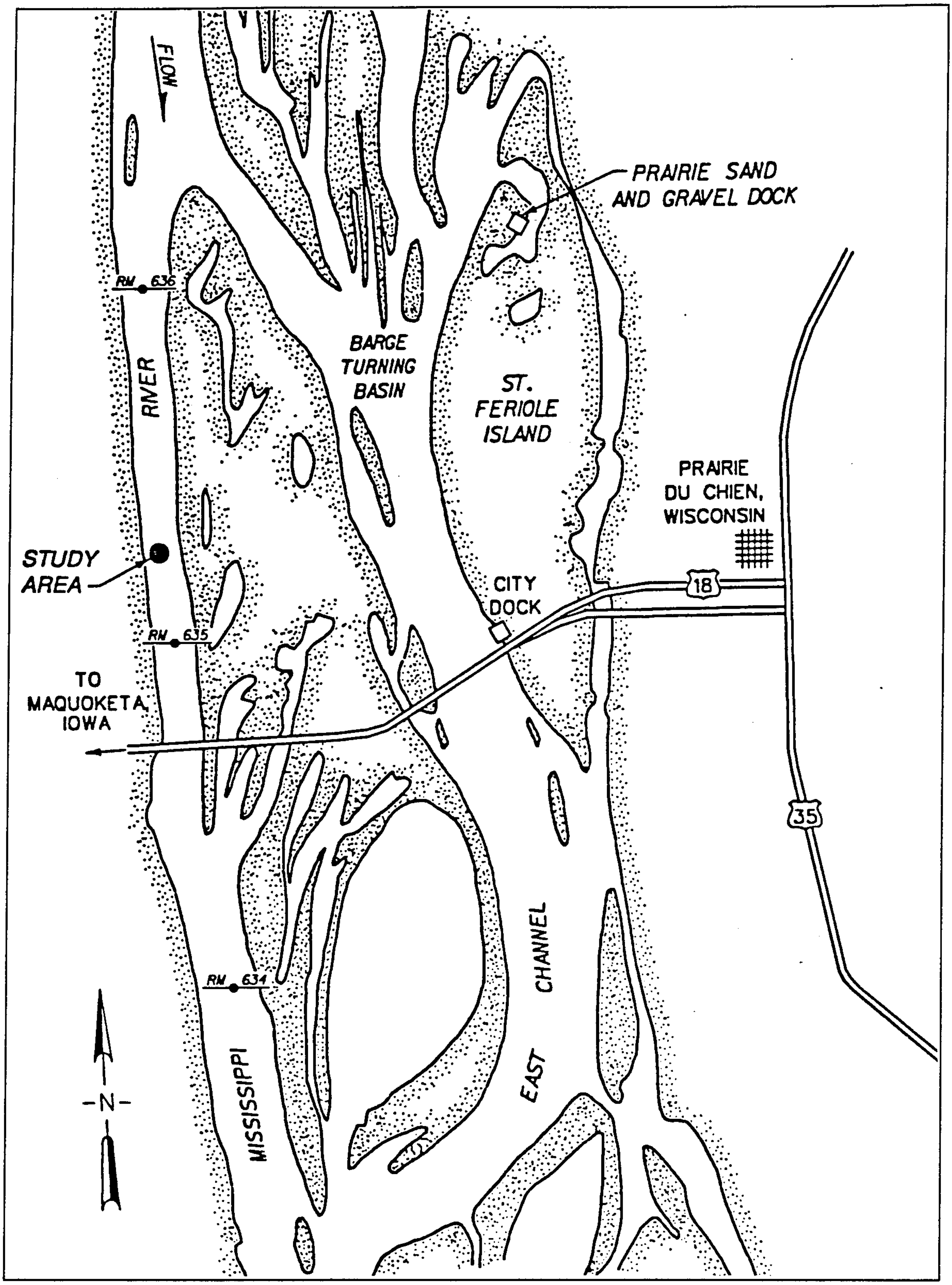


Figure 6. Study area at the mussel bed located in Pool 10, RM 635.2

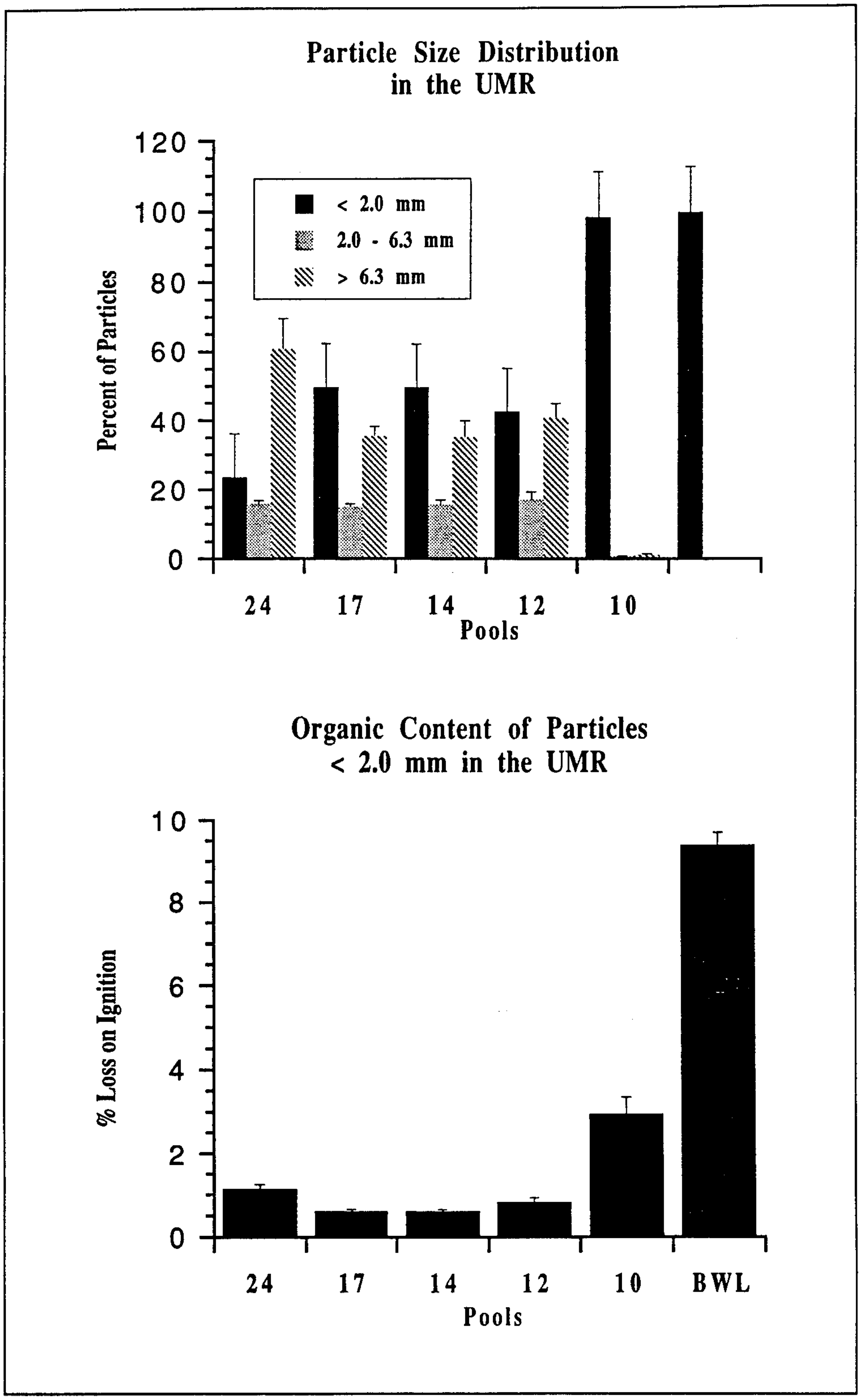


Figure 7. Characteristics of sediments in five pools in the UMR (values are the mean of three replicates from the nearshore and three from a farshore location on the mussel bed). For comparison, data from a backwater lake (BWL) are included. Grain size analysis (top) and percent loss on ignition (bottom)

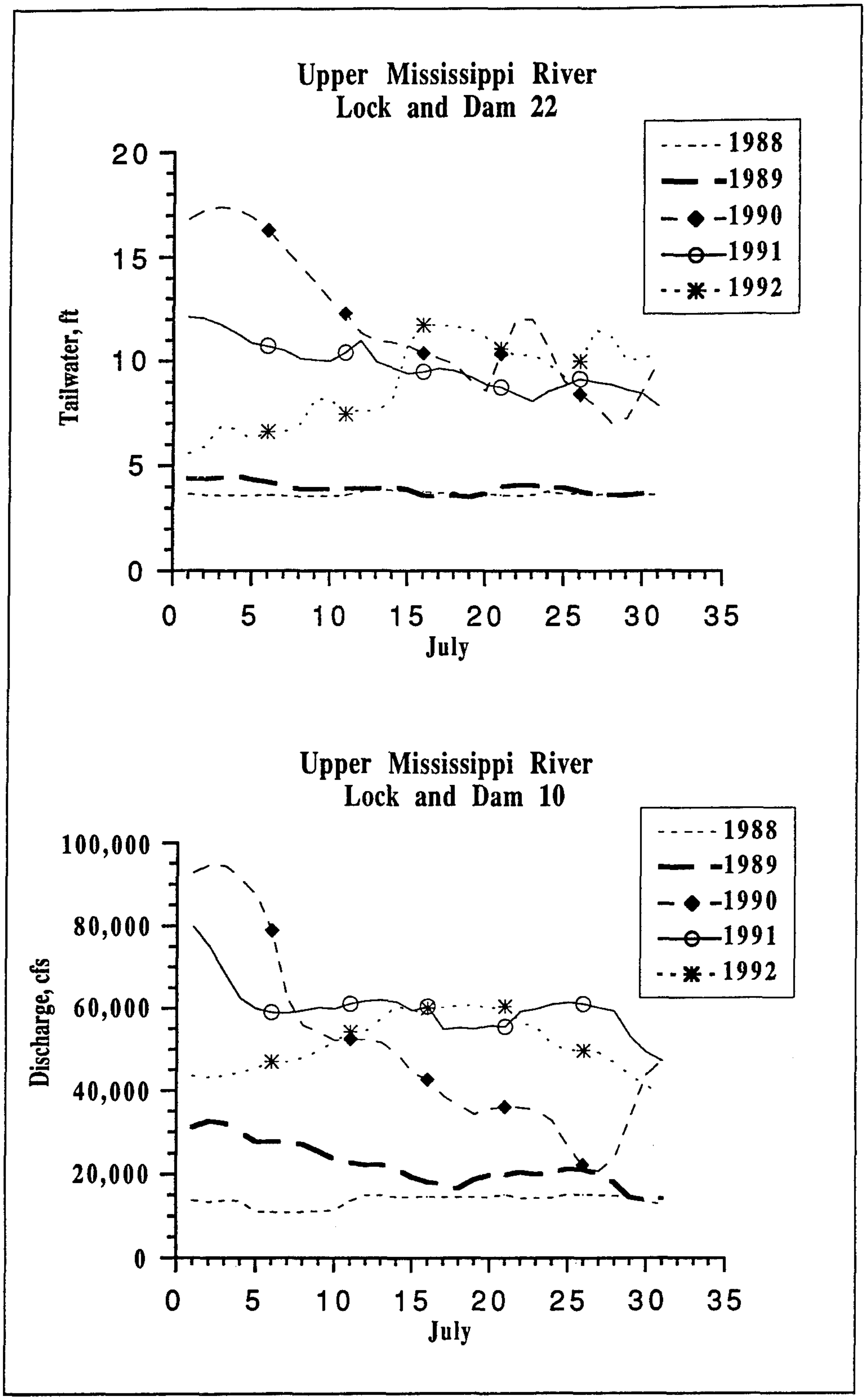


Figure 8. Physical conditions at selected sites in the UMR, July, 1988-92. Water levels (ft) in the tailwater of Lock and Dam 22 (top) and discharge (cfs) at Lock and Dam 10 (bottom)

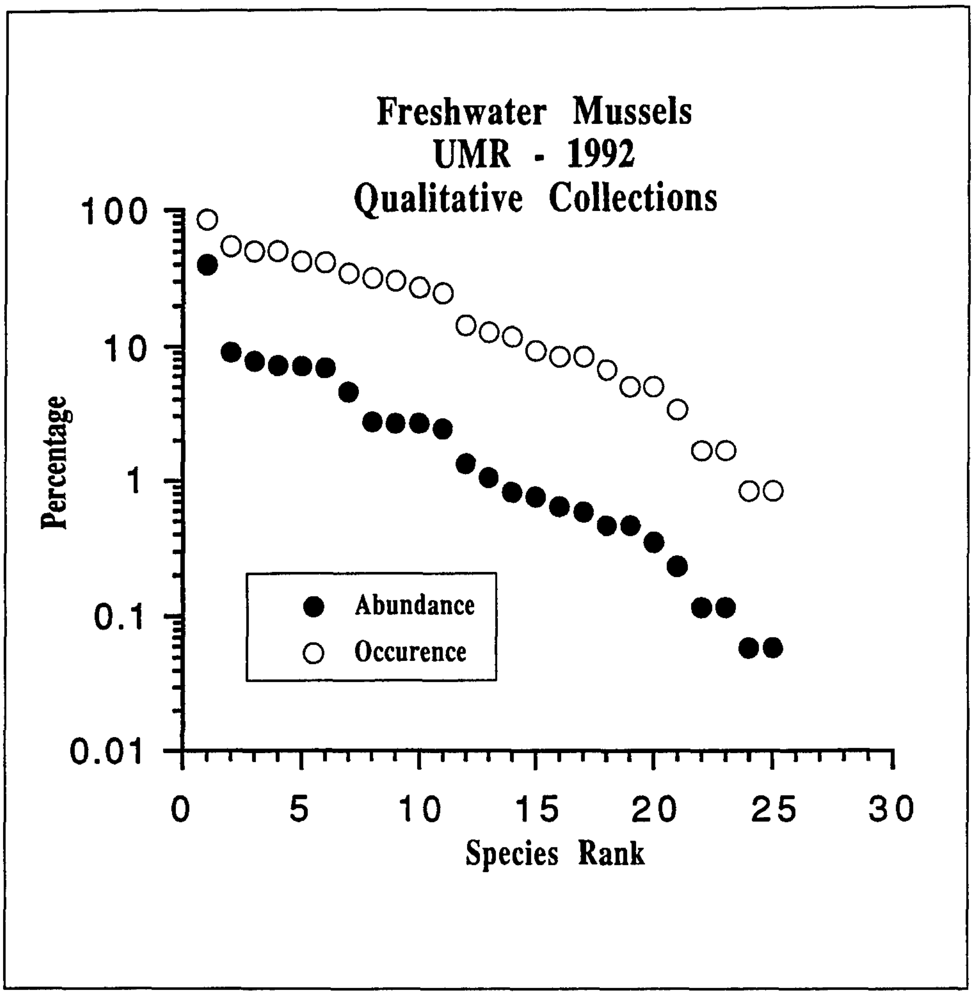


Figure 9. Percentage abundance and occurrence versus species rank for all mussels collected using qualitative methods at RM 299.6, 450.4, 504.8, 571.5, and 635.2, in the UMR, 1992

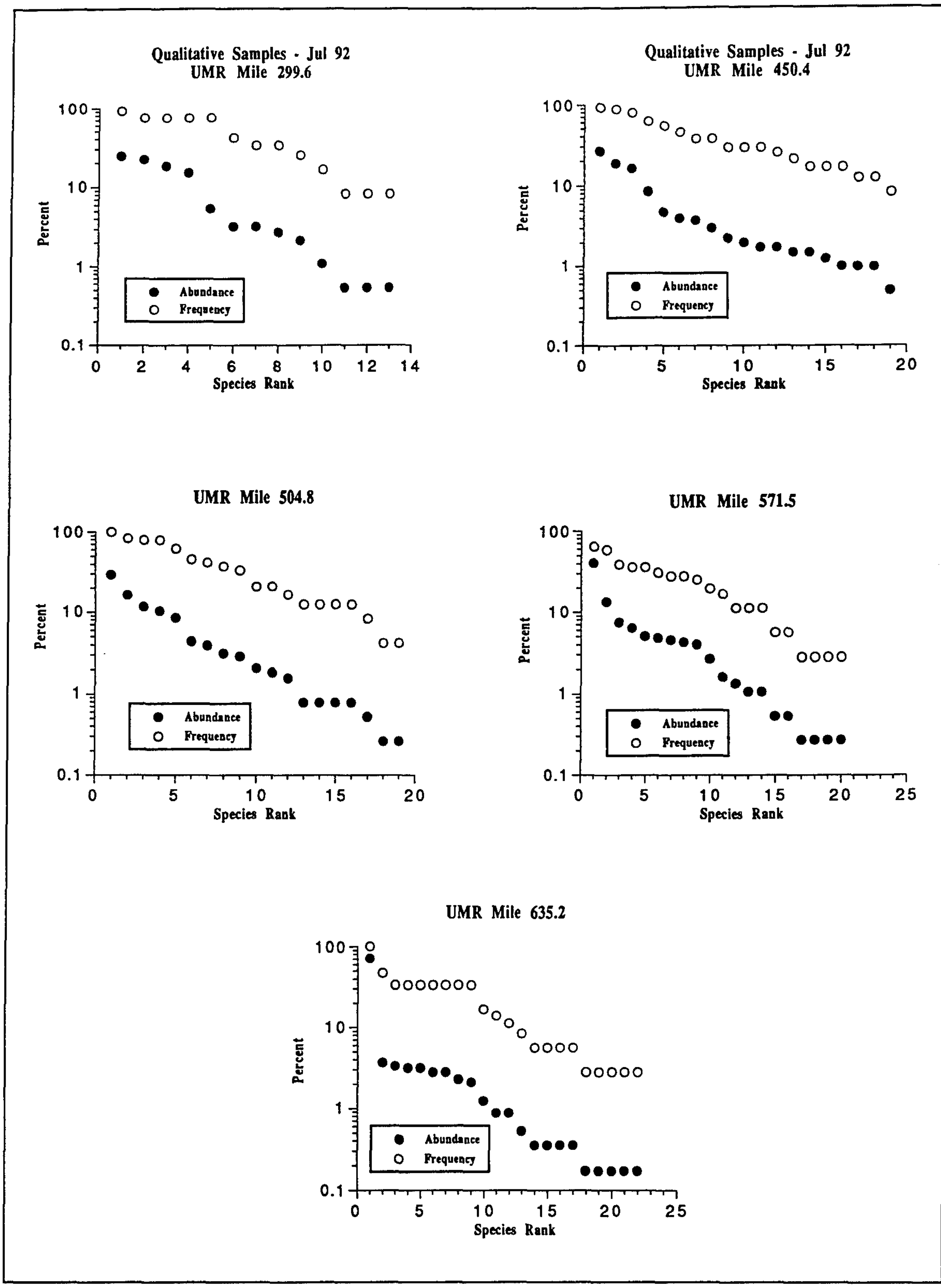


Figure 10. Percentage abundance versus species rank for mussels collected using qualitative methods at five locations in the UMR, 1992

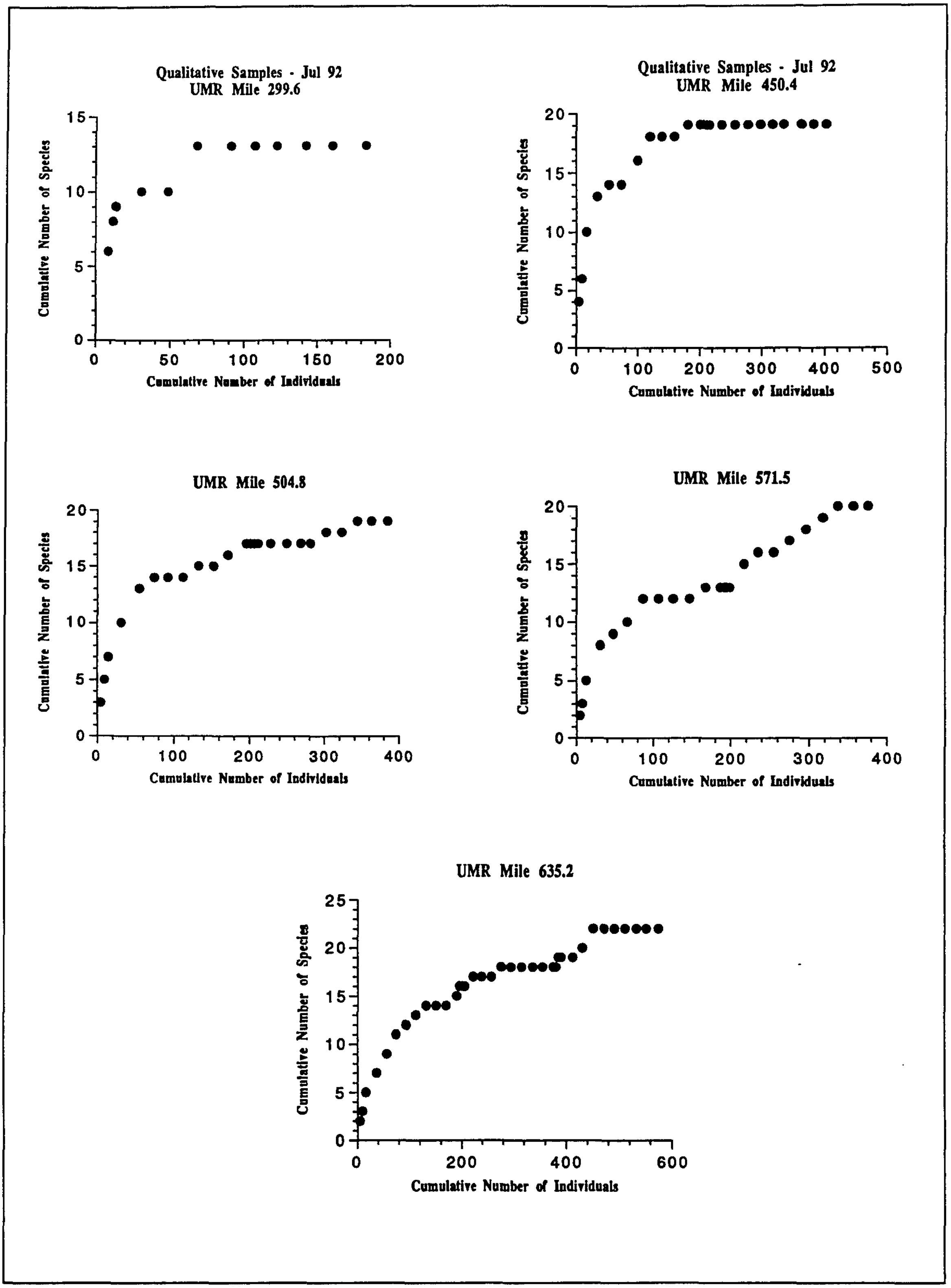


Figure 11. Cumulative number of species versus cumulative number of individuals collected using qualitative methods at five locations in the UMR, 1992

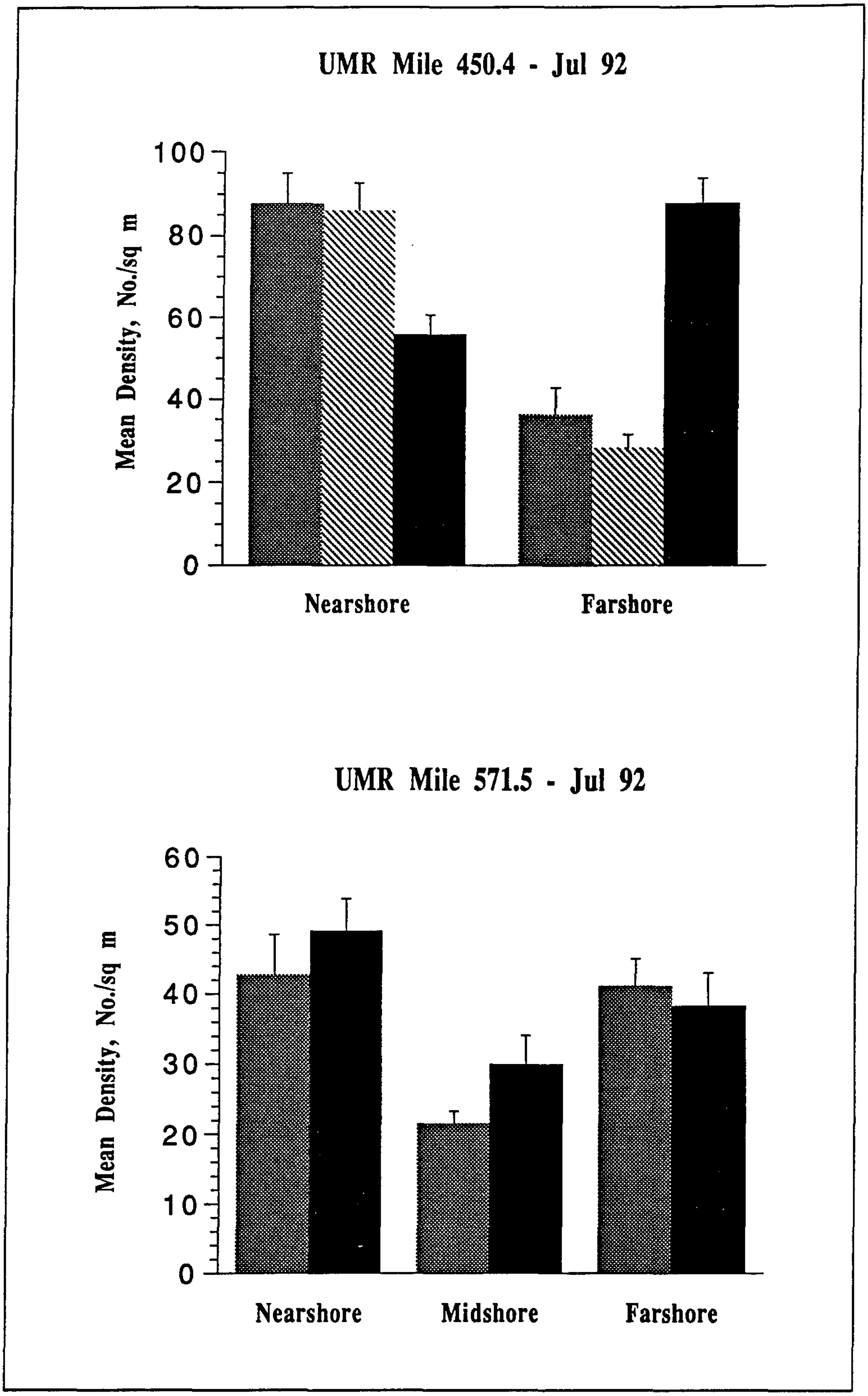


Figure 12. Mean density (individuals/sq m) and standard error of the mean for freshwater mussels collected at two locations in the UMR, 1992

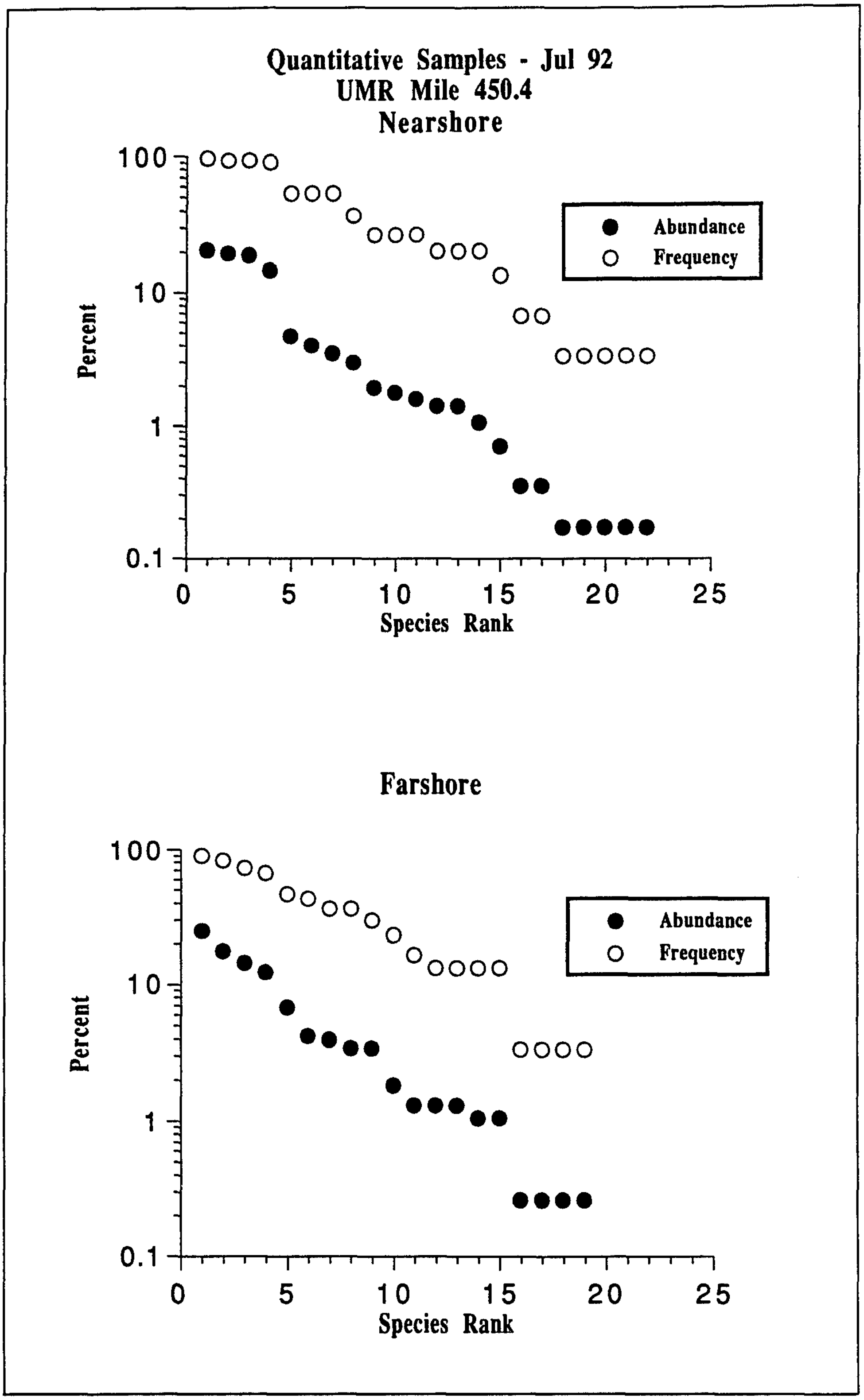


Figure 13. Percentage abundance and occurrence versus species rank for mussels collected using quantitative methods at a nearshore and farshore site, UMR mile 450.4, 1992

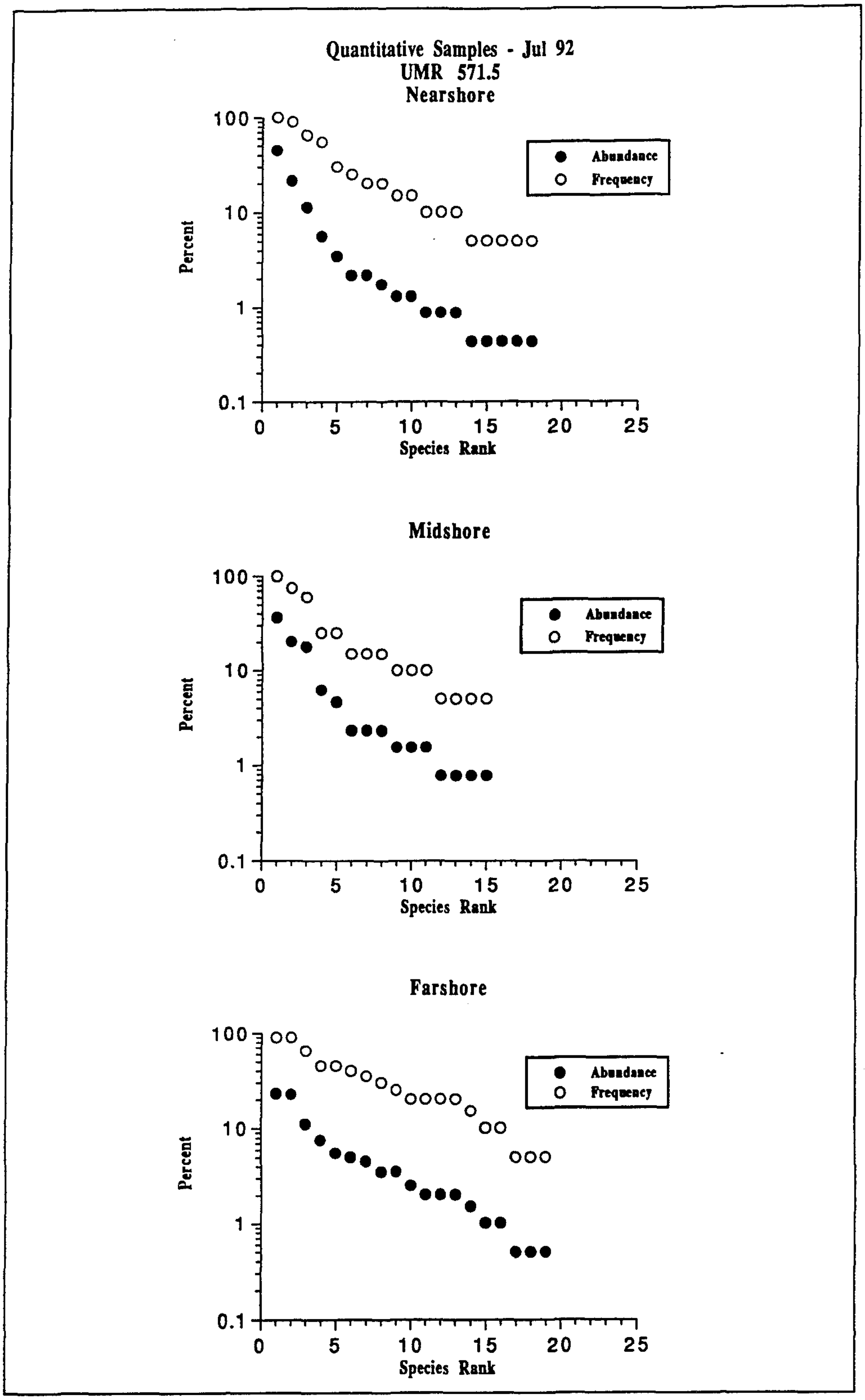


Figure 14. Percentage abundance and occurrence versus species rank for mussels collected using quantitative methods at a nearshore, midshore, and farshore site, UMR mile 571.5, 1992

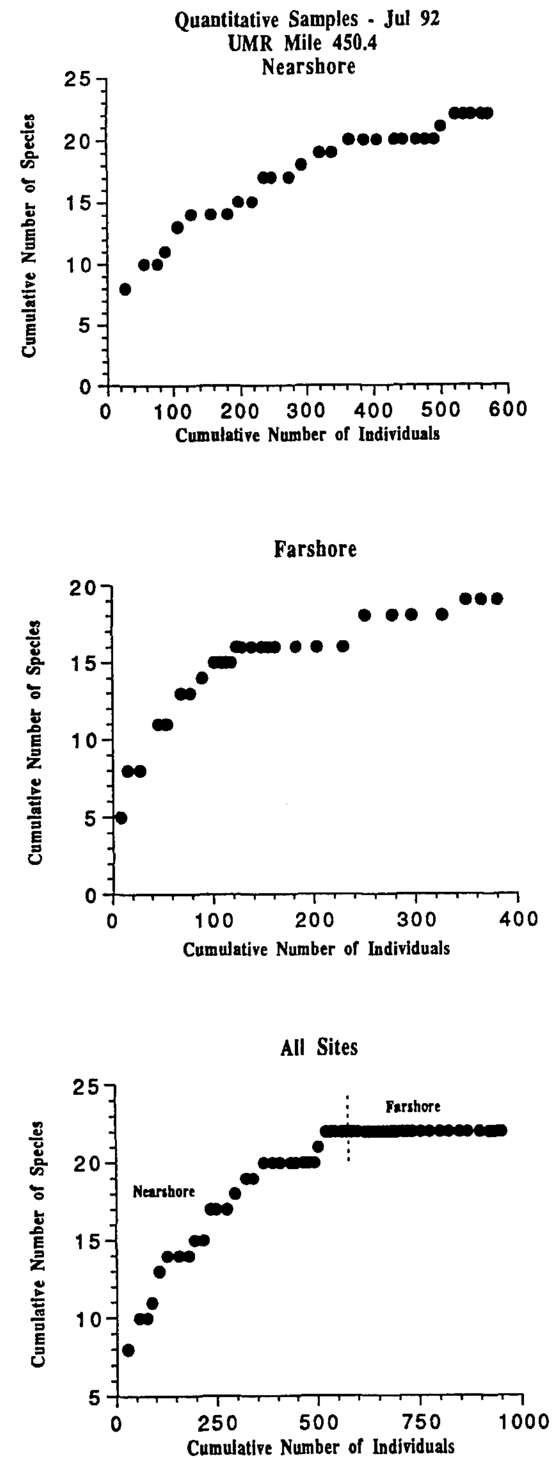


Figure 15. Cumulative number of species versus cumulative number of individuals collected using quantitative methods at UMR mile 450.4, 1992

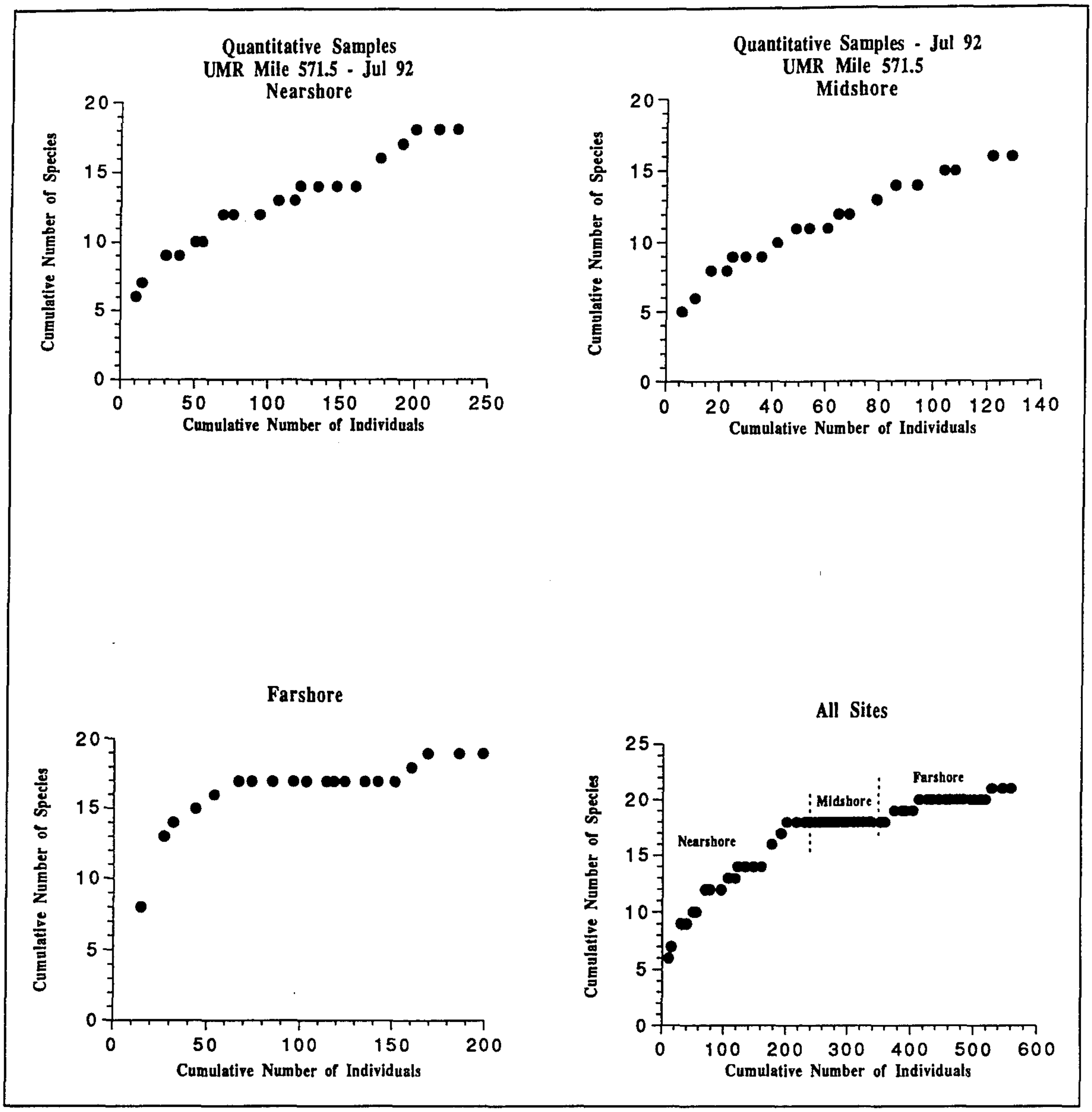


Figure 16. Cumulative number of species versus cumulative number of individuals collected using quantitative methods at UMR mile 571.5, 1992

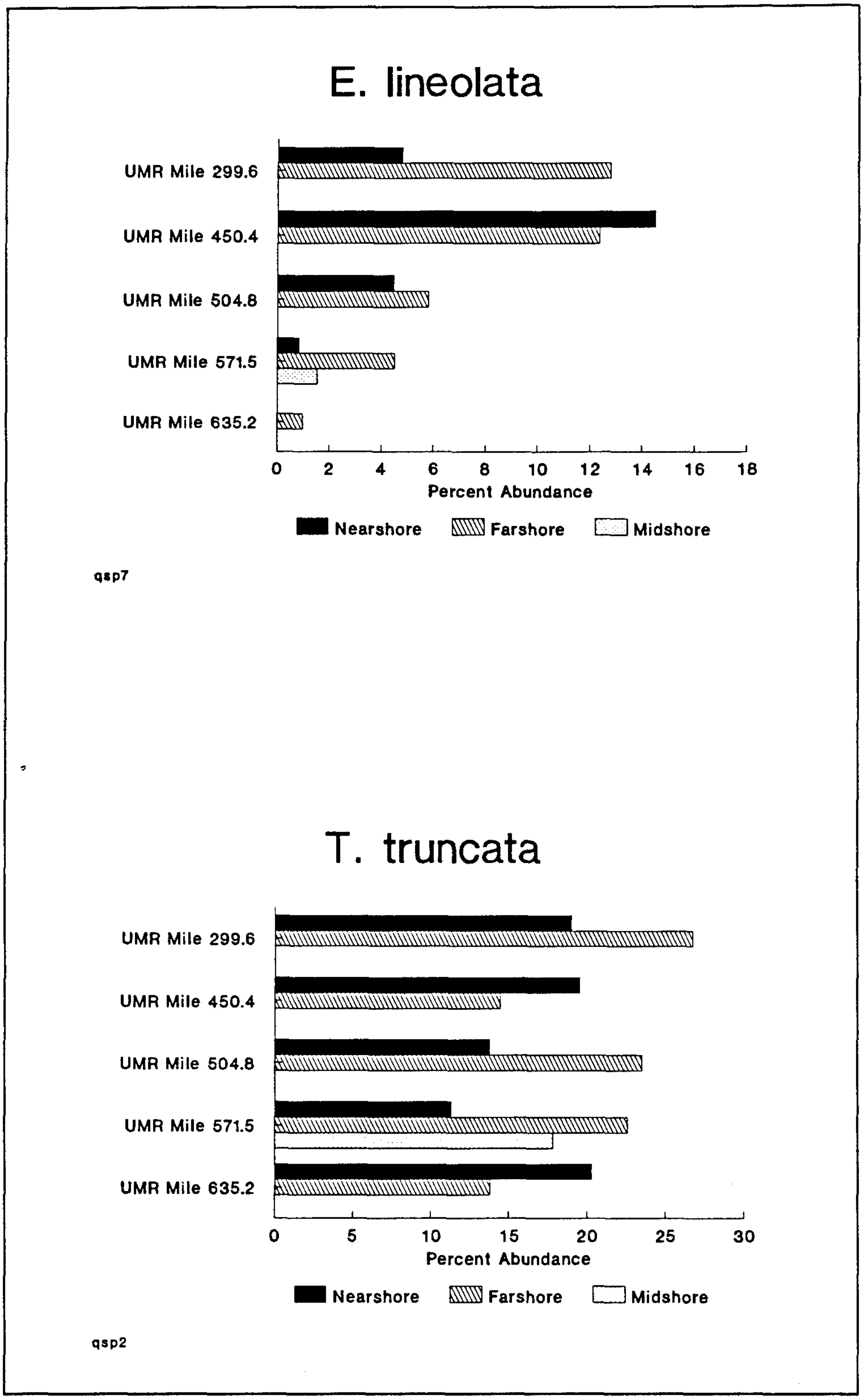


Figure 17. Percentage abundance of *Ellipsaria lineolata* and *Truncilla truncata* at five locations in the UMR, 1992

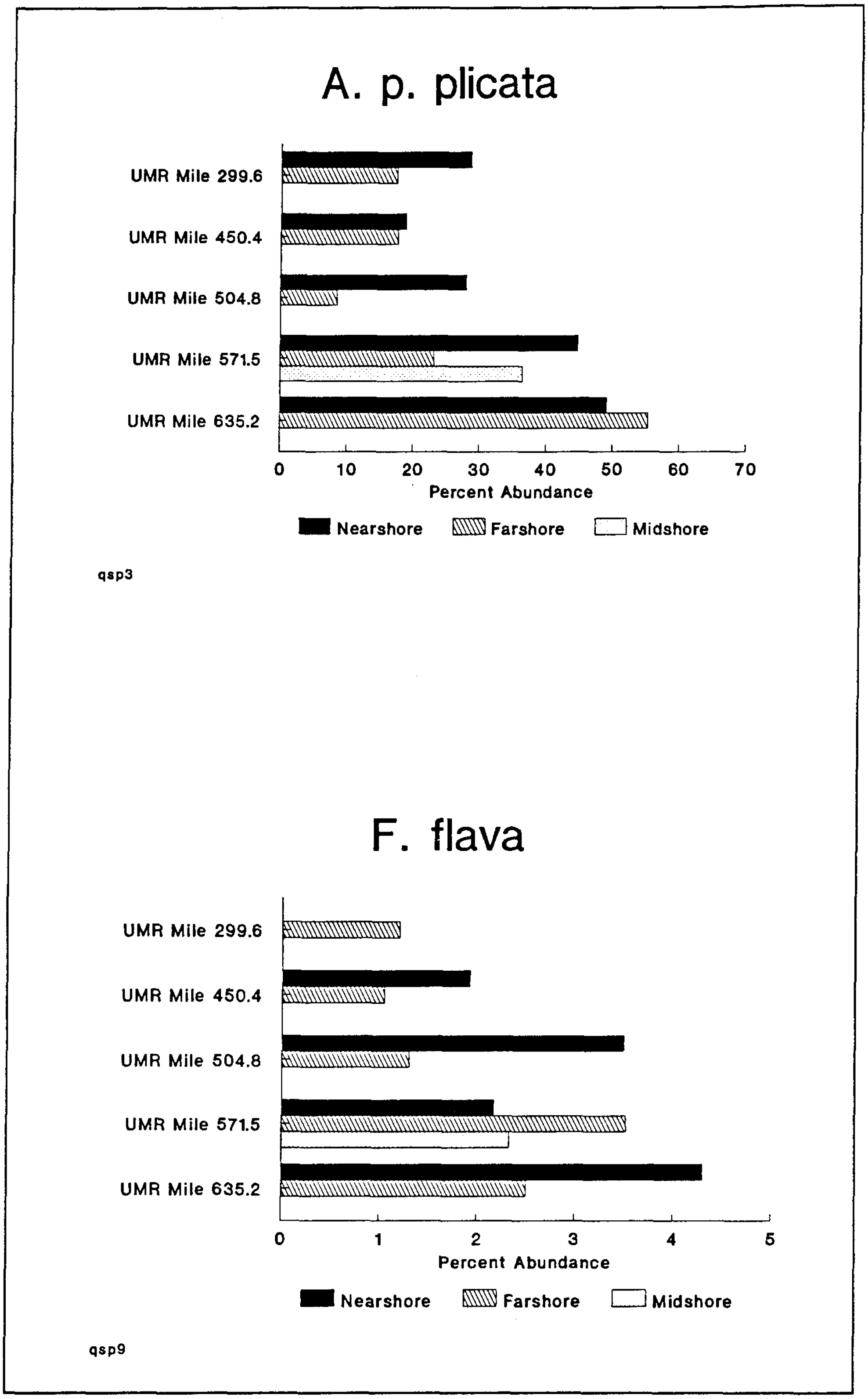


Figure 18. Percentage abundance of *Amblema plicata plicata* and *Fusconaia flava* at five locations in the UMR, 1992

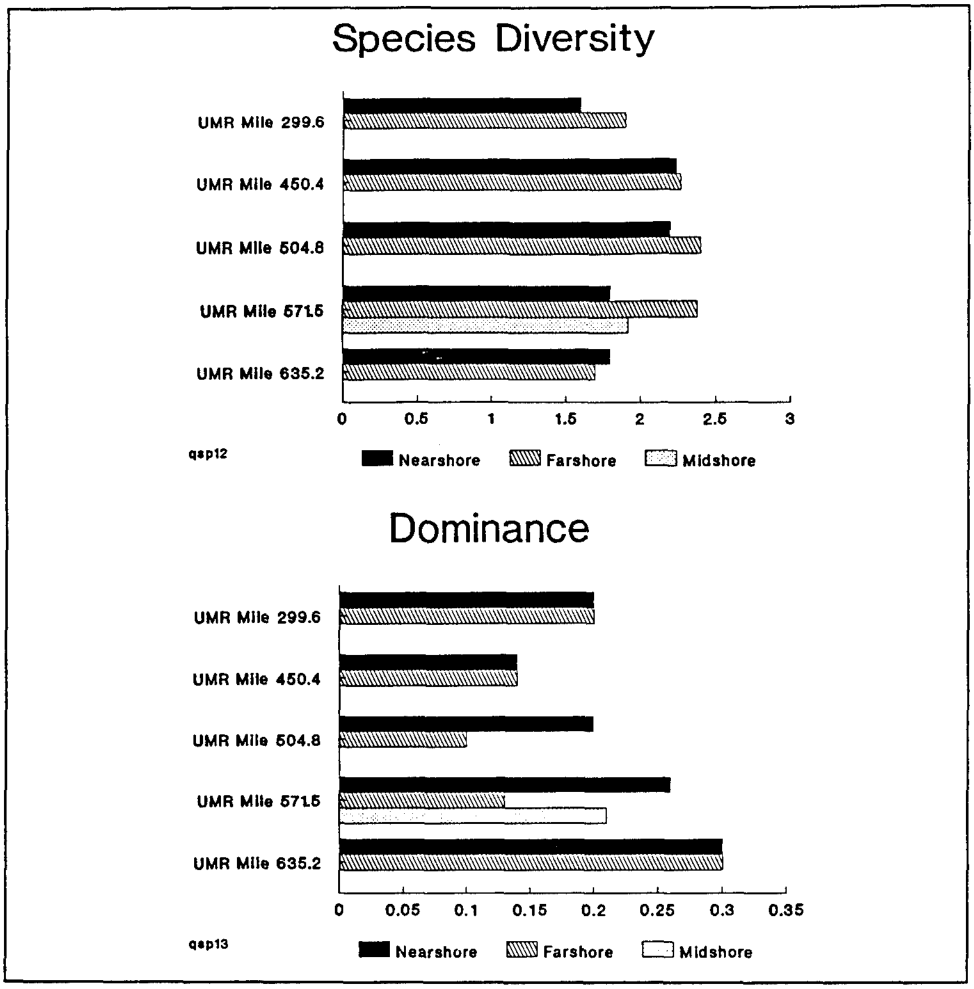
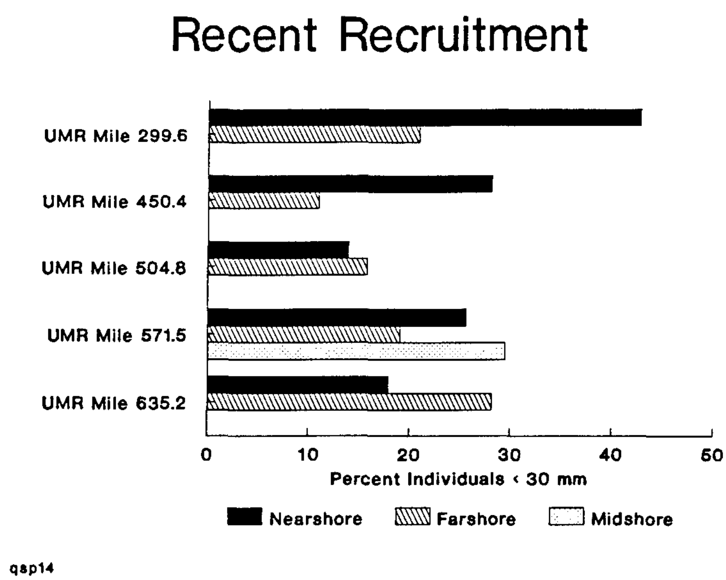


Figure 19. Species diversity (H') and dominance of freshwater mussels at five locations in the UMR, 1992



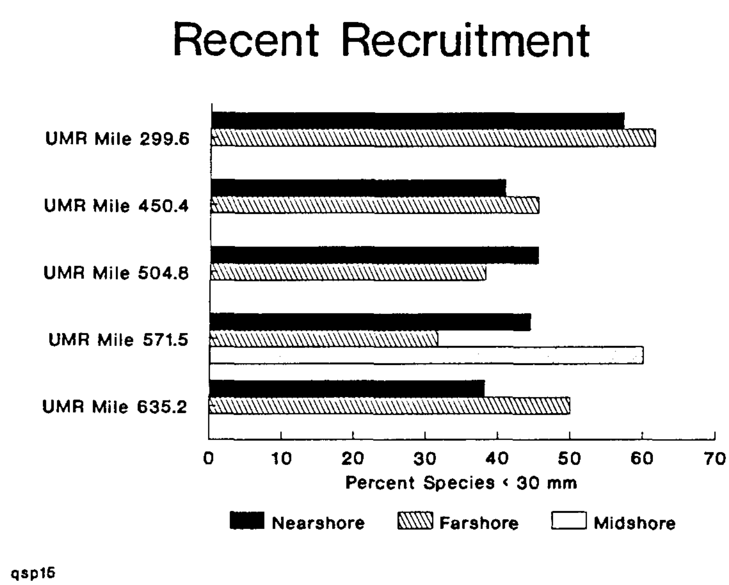


Figure 20. Evidence of recent recruitment based on percent individuals and percent species less than 30 mm total shell length at five locations in the UMR, 1992

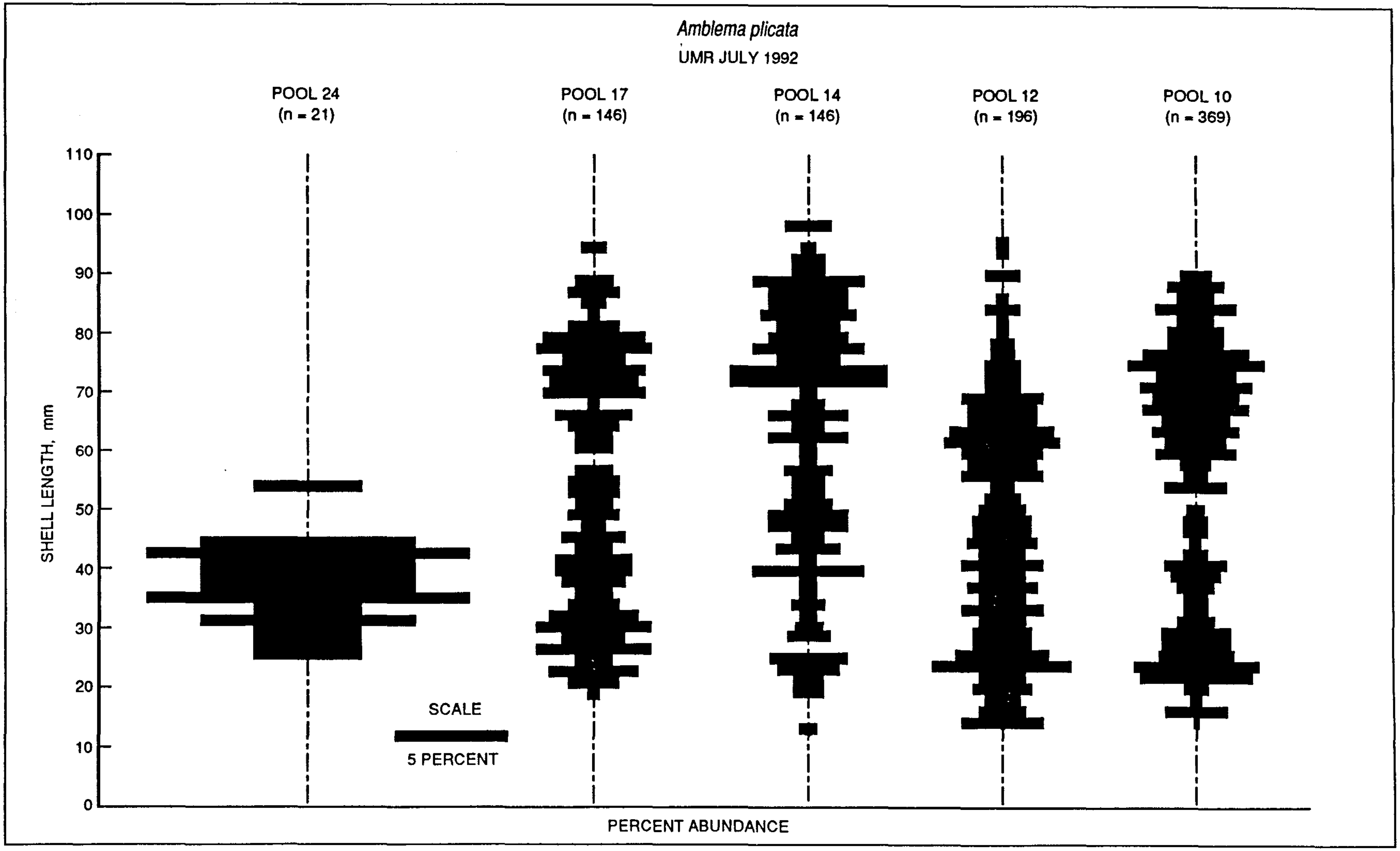


Figure 21. Interpool comparison of size demography of *Amblema plicata plicata* populations in the upper Mississippi River, July 1992

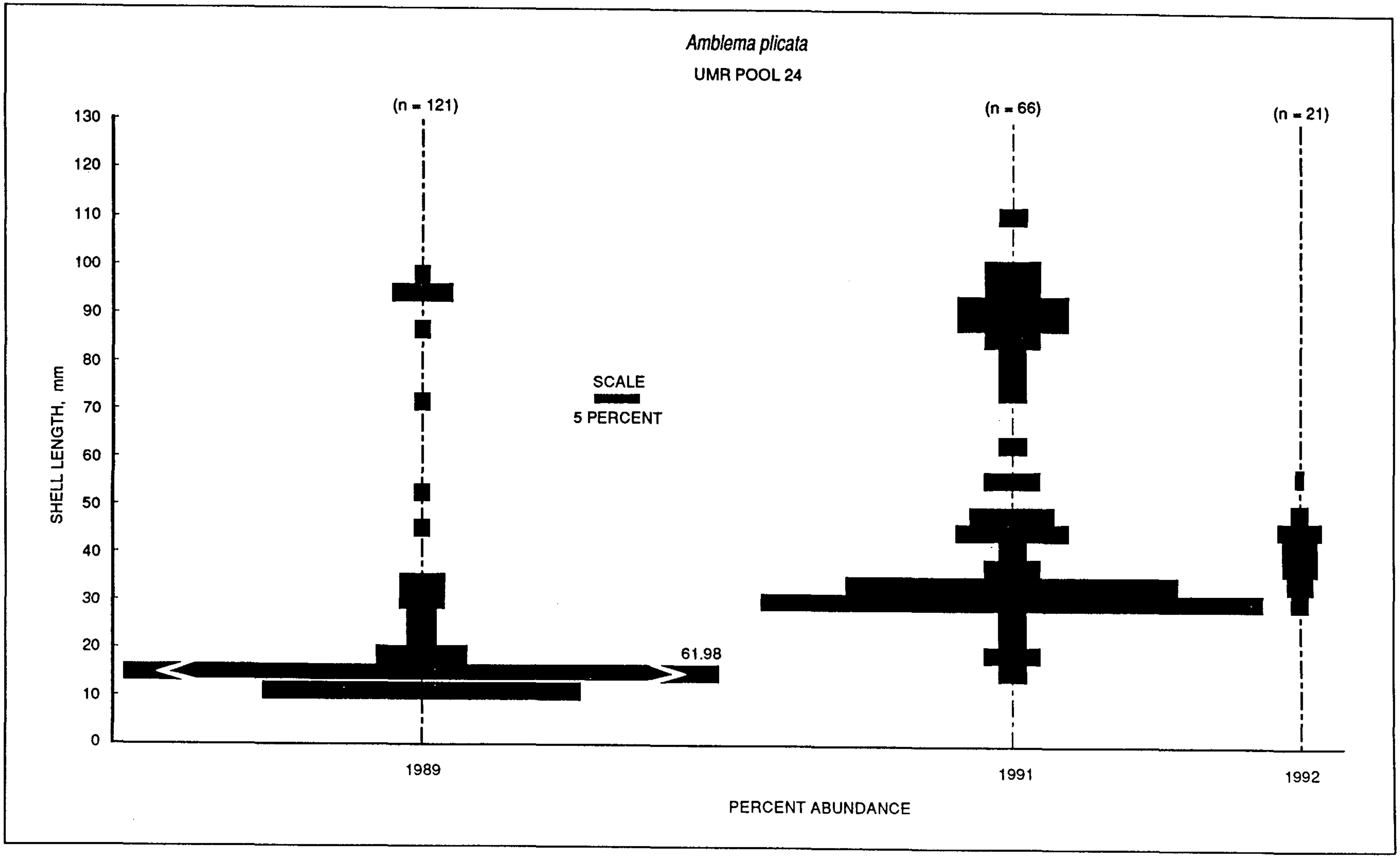


Figure 22. Size demography of the *Amblema plicata plicata* population in Pool 24, 1988 to 1992

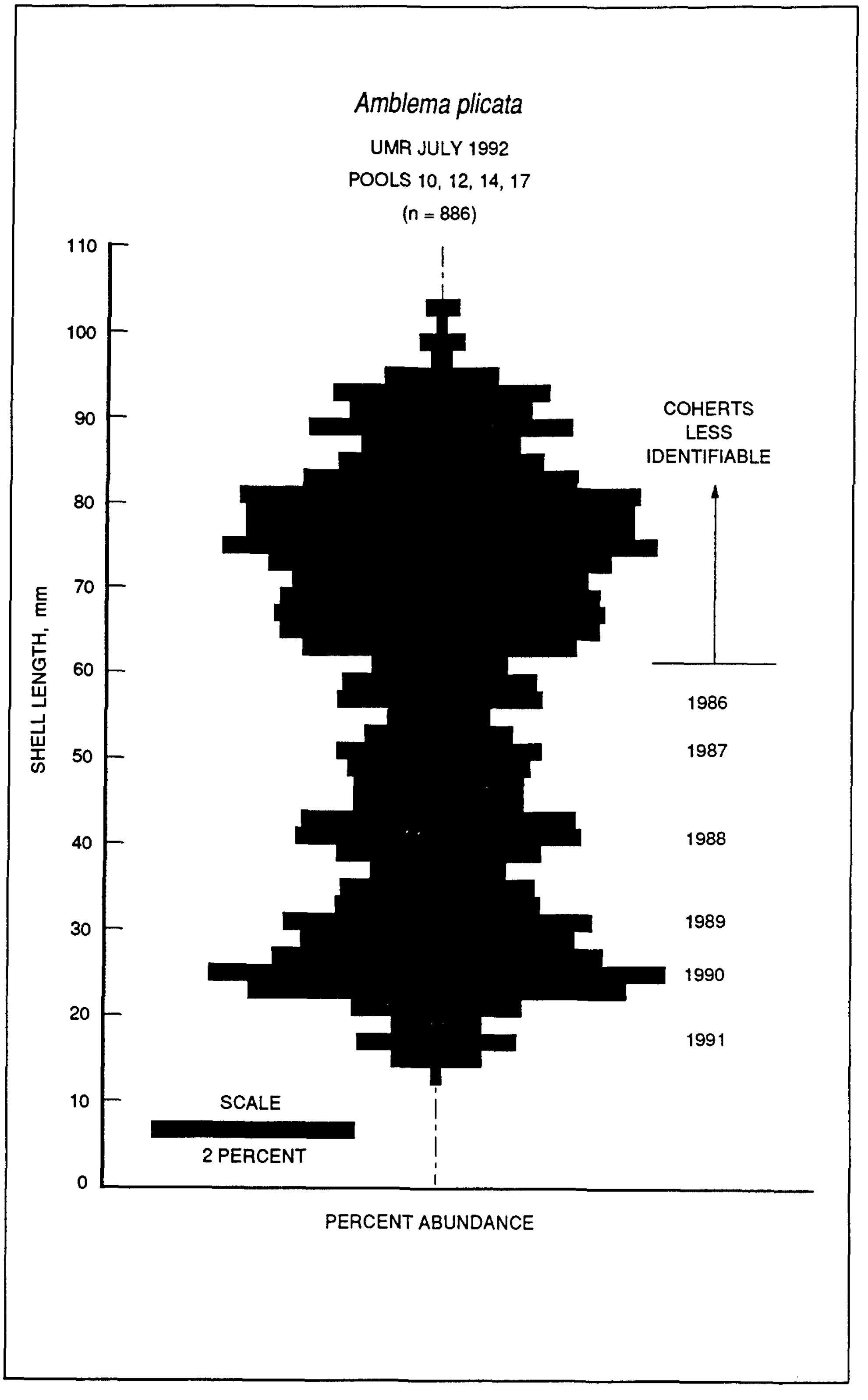


Figure 23. Composite representation of size demography of July 1992 *Amblema plicata plicata* populations in Pools 17, 14, 12, and 10, with year classes of recent recruits indicated

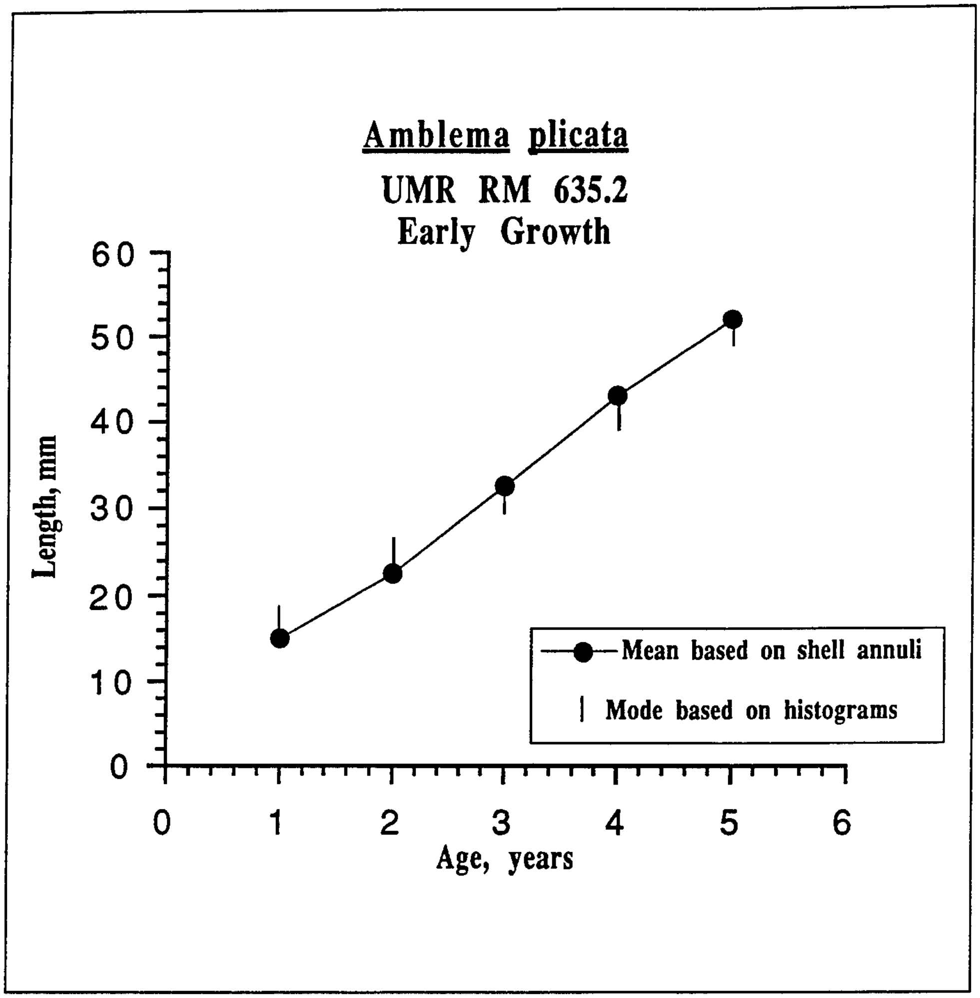


Figure 24. Models of early growth of *Amblema plicata plicata* based on shell-annuli-to-length estimates and modal lengths of cohorts distinguished in the shell-length frequency histogram

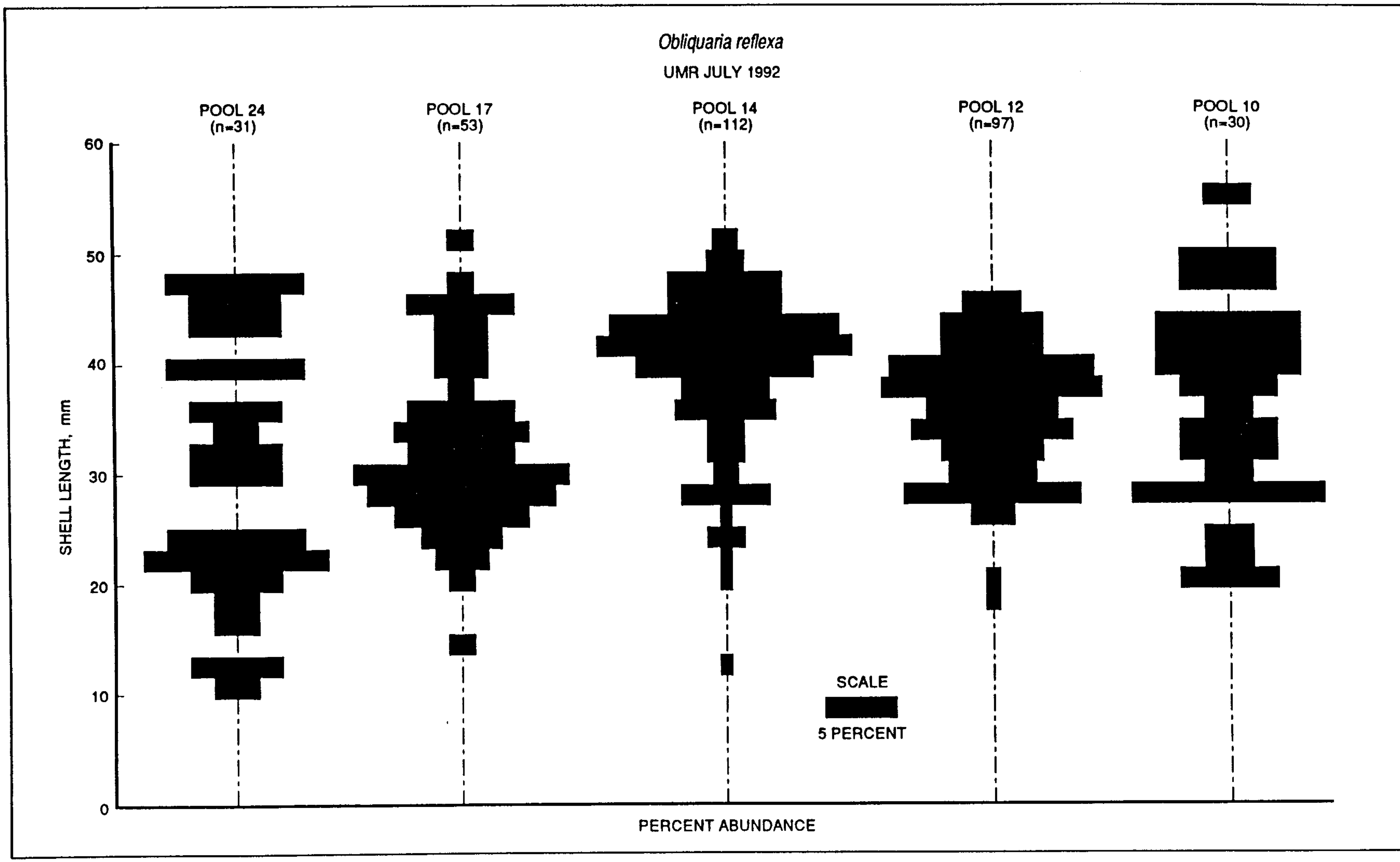


Figure 25. Interpool comparison of size demography of *Obliquaria reflexa* populations in the upper Mississippi River, July 1992

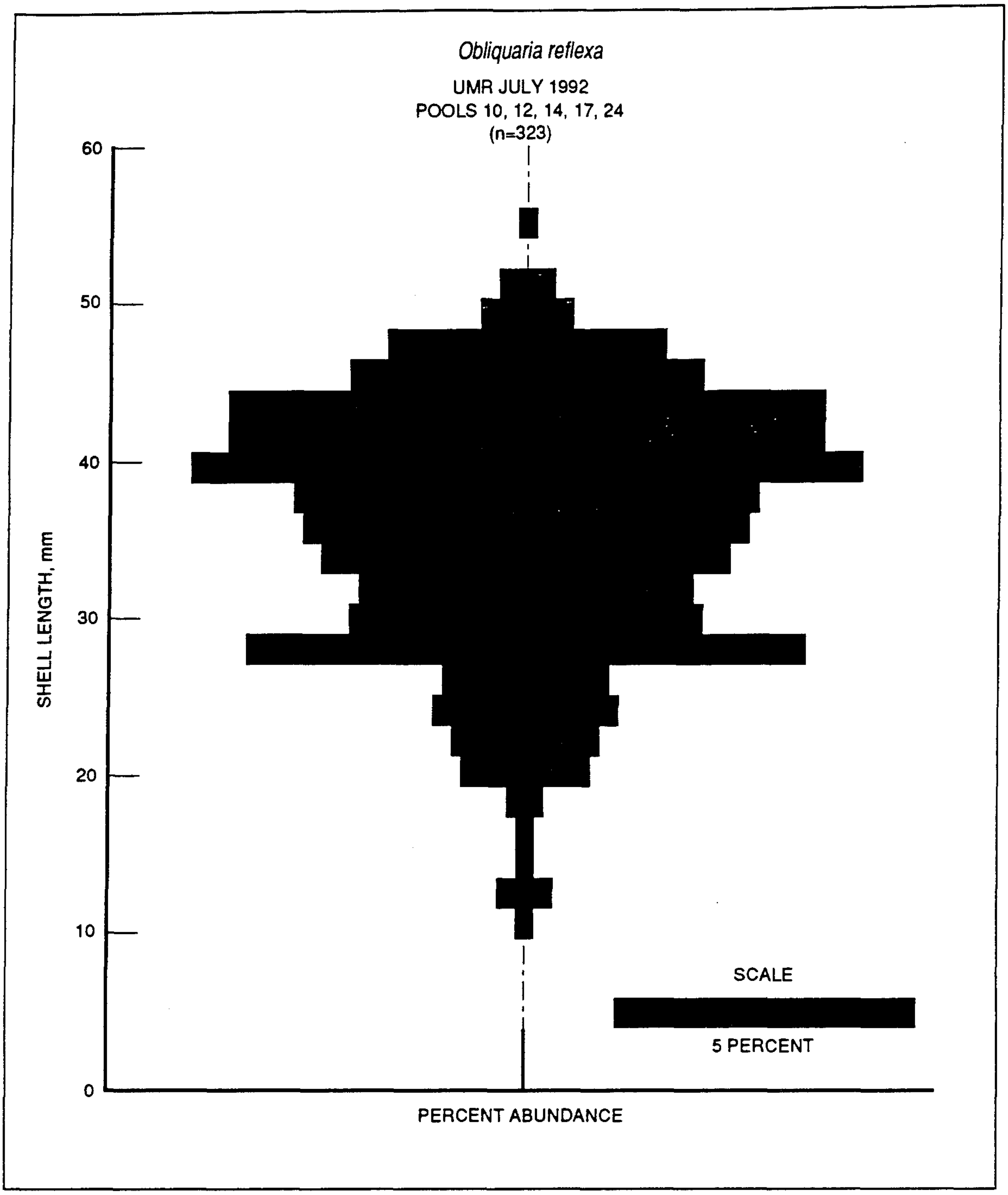


Figure 26. Composite representation of size demography of July 1992 *Obliquaria reflexa* in Pools 24, 17, 14, 12, and 10

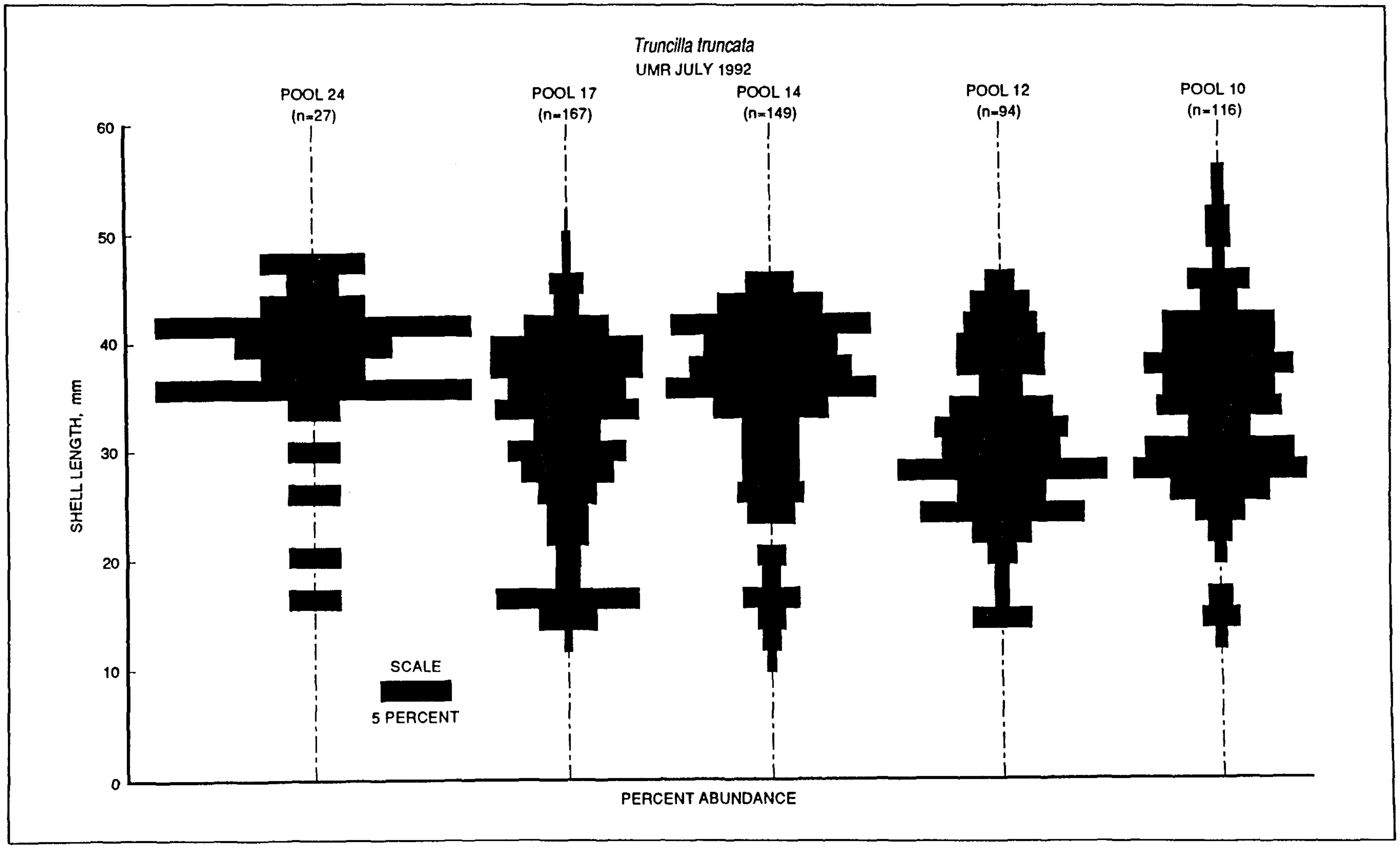


Figure 27. Interpool comparison of size demography of *Truncilla truncata* populations in the upper Mississippi River, July 1992

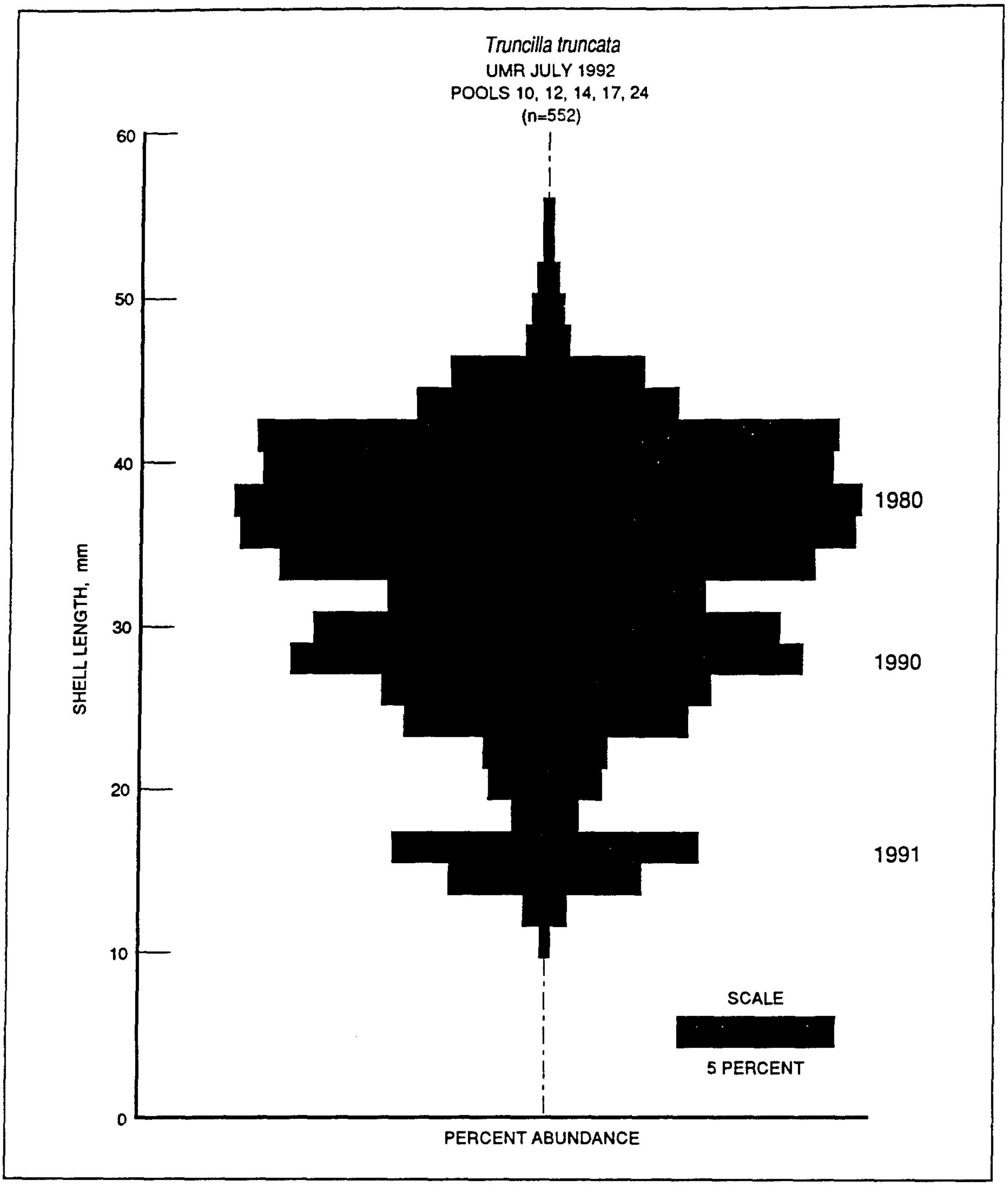


Figure 28. Composite representation of size demography of *Truncilla truncata* in July 1992 in Pools 24, 17, 14, 12, and 10, with year classes indicated

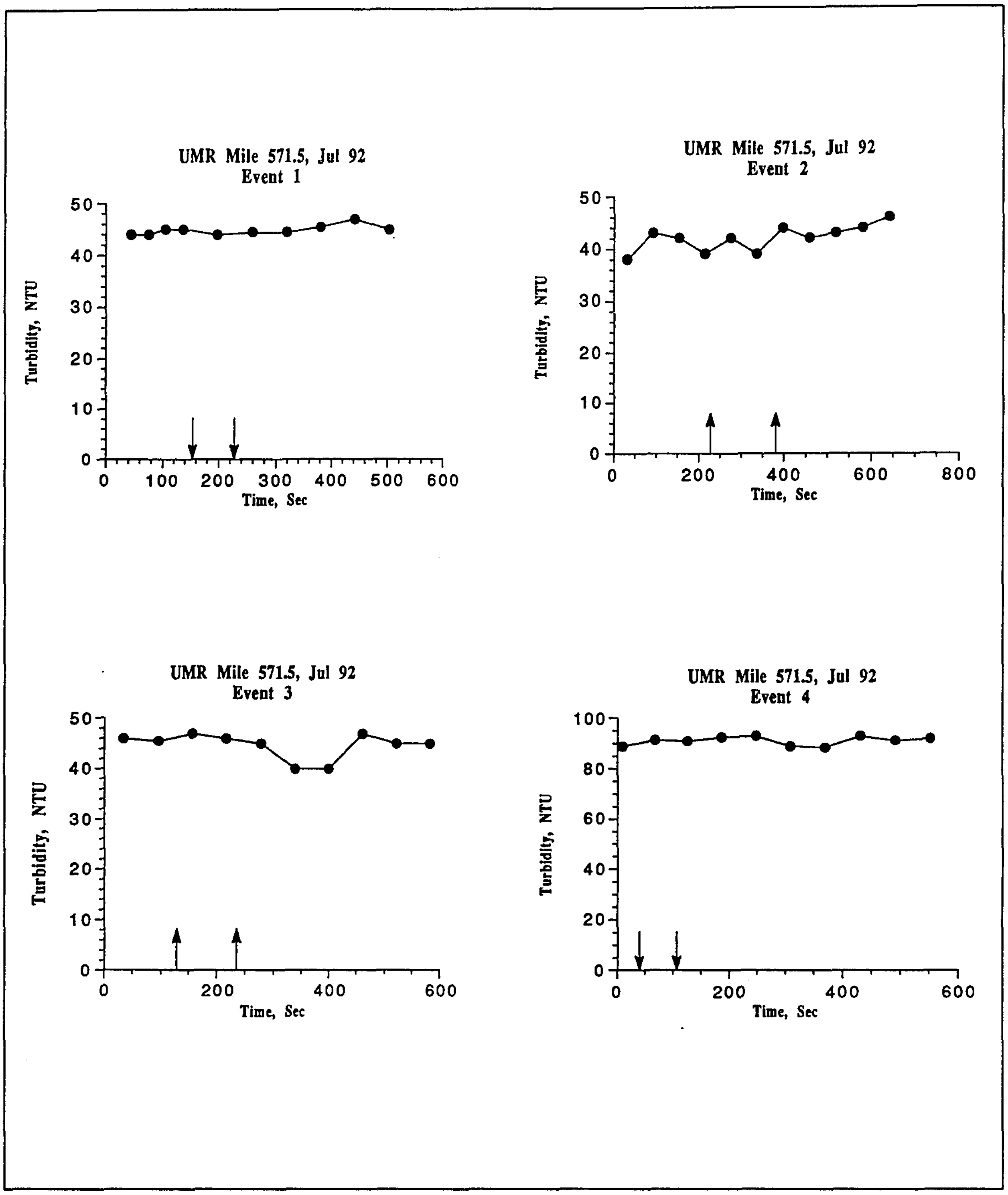


Figure 29. Changes in turbidity following passage (Events 1-4) of a commercial vessel at UMR Mile 571.5, 1992

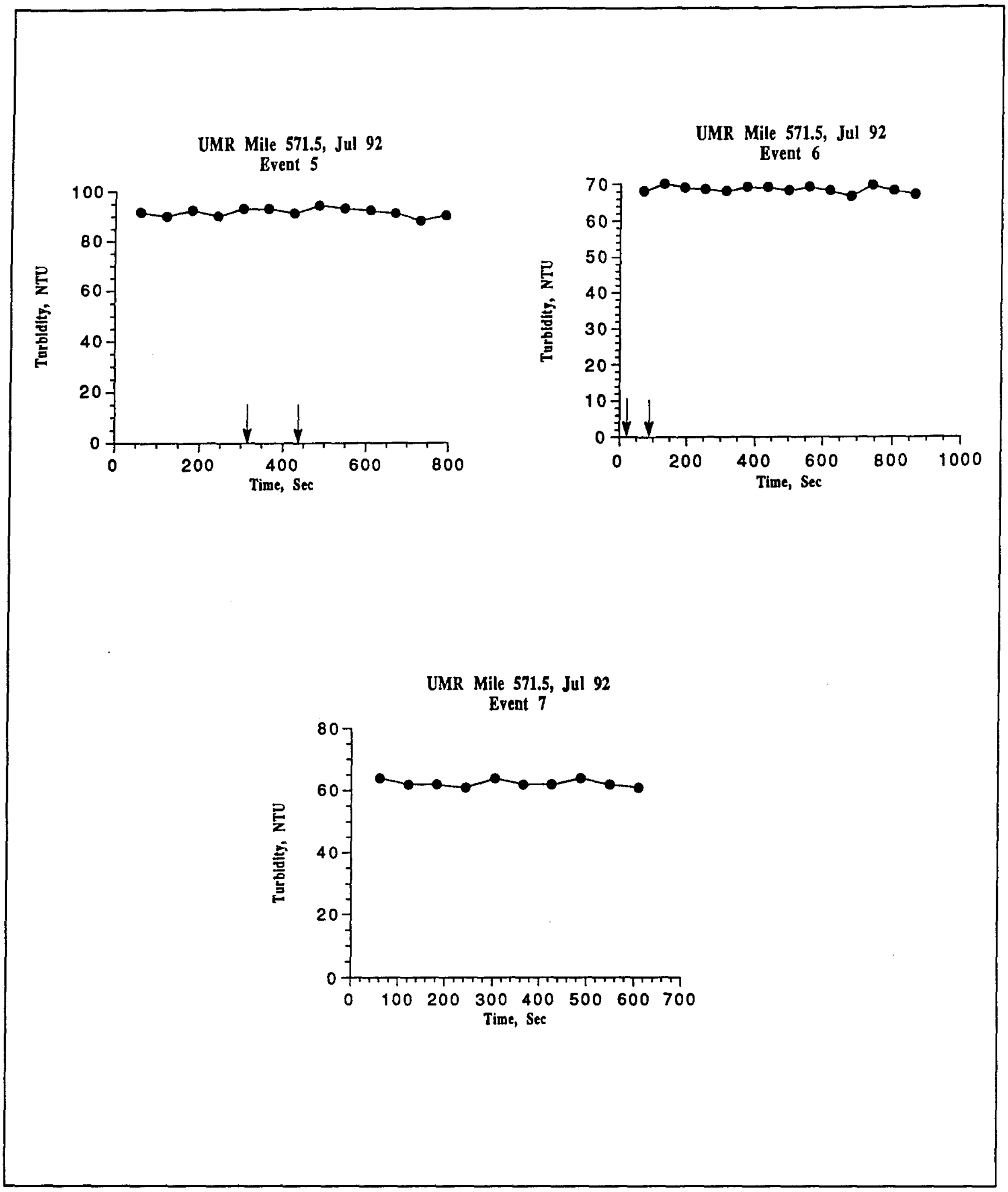


Figure 30. Changes in turbidity following passage (Events 5-7) of a commercial vessel at UMR Mile 571.5, 1992

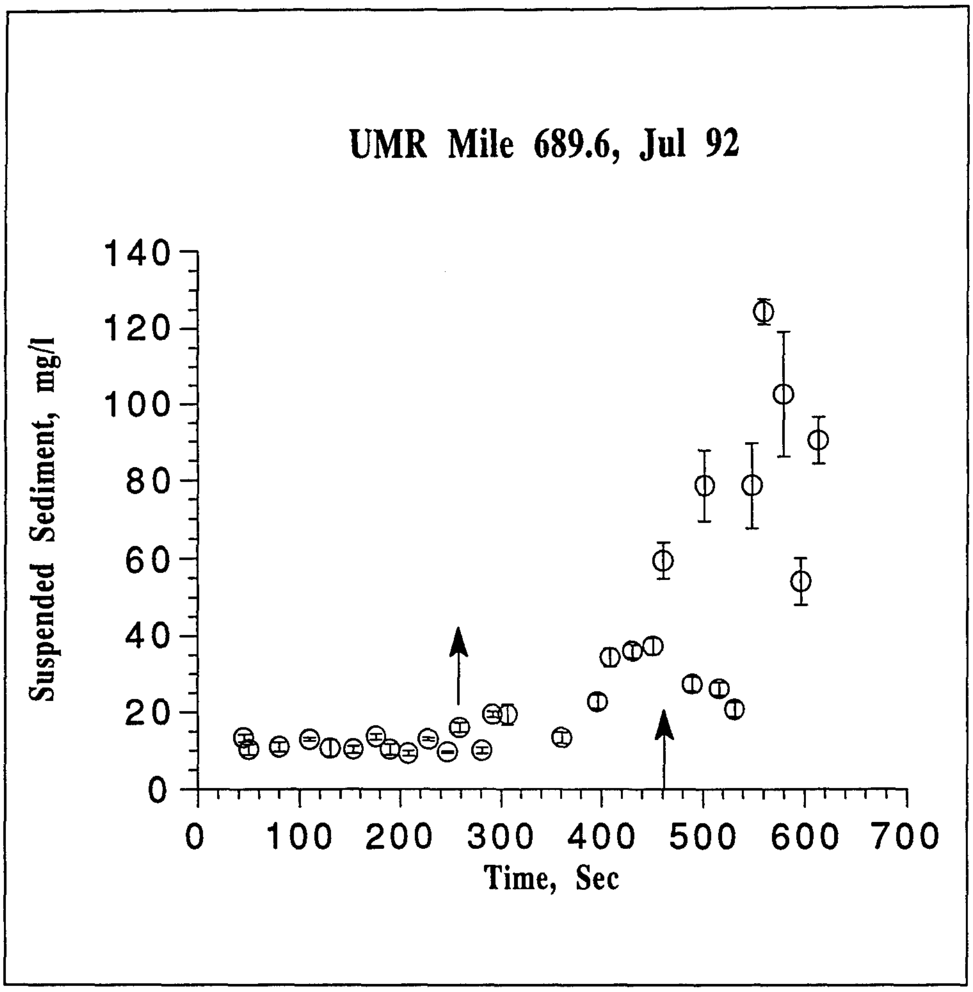


Figure 31. Changes in suspended solids (mg/ℓ) following passage of two 21-ft skiffs, UMR Mile 689.6, 1992

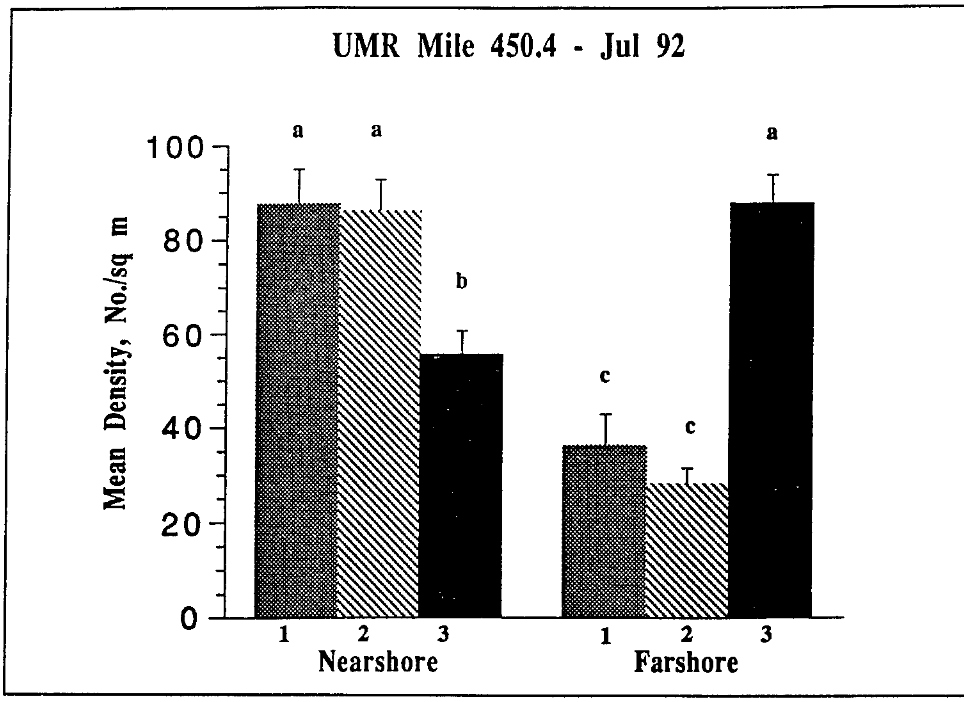


Figure 32. Mean density (individuals/sq m) and standard error of the mean for freshwater mussels collected at UMR Mile 450.4, 1990 and 1992

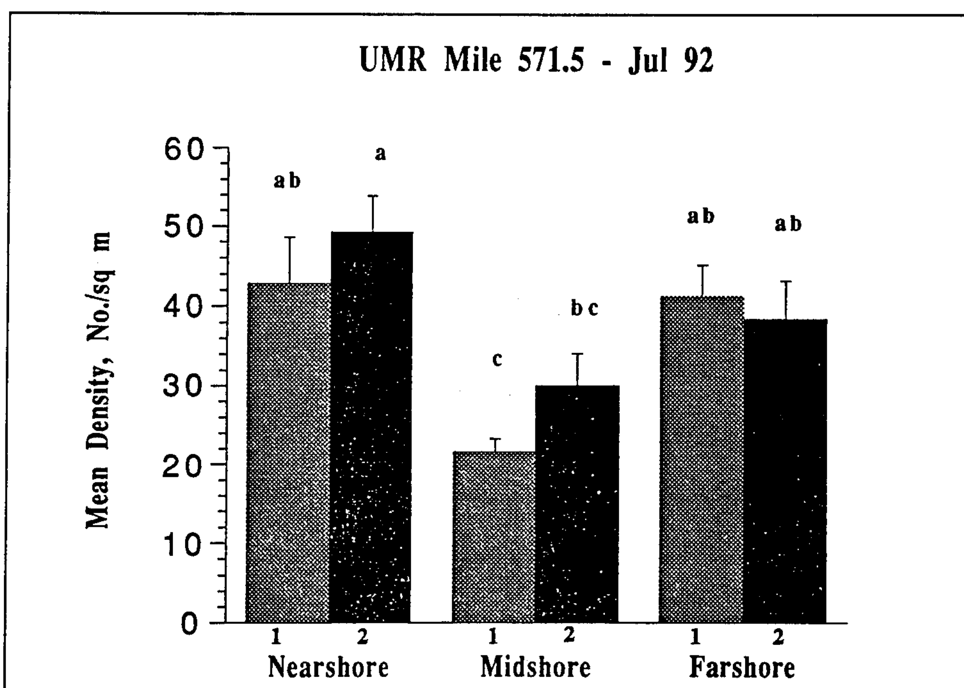


Figure 33. Mean density (individuals/sq m) and standard error of the mean for freshwater mussels collected at UMR Mile 571.5, 1990 and 1992

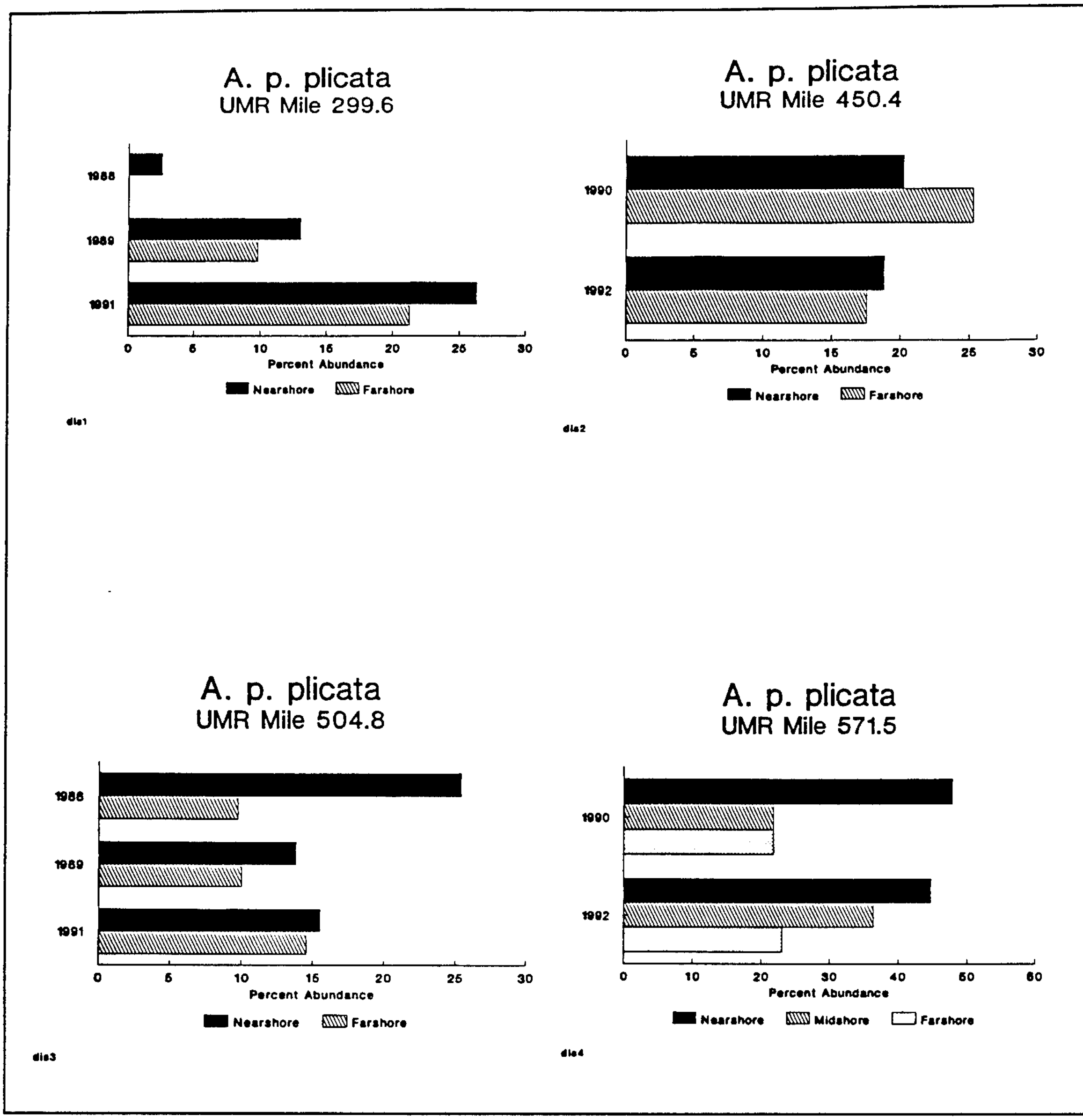


Figure 34. Percent abundance of *Amblema plicata plicata* at UMR Miles 299.6, 450.4, 504.8, and 571.5, 1988-1992

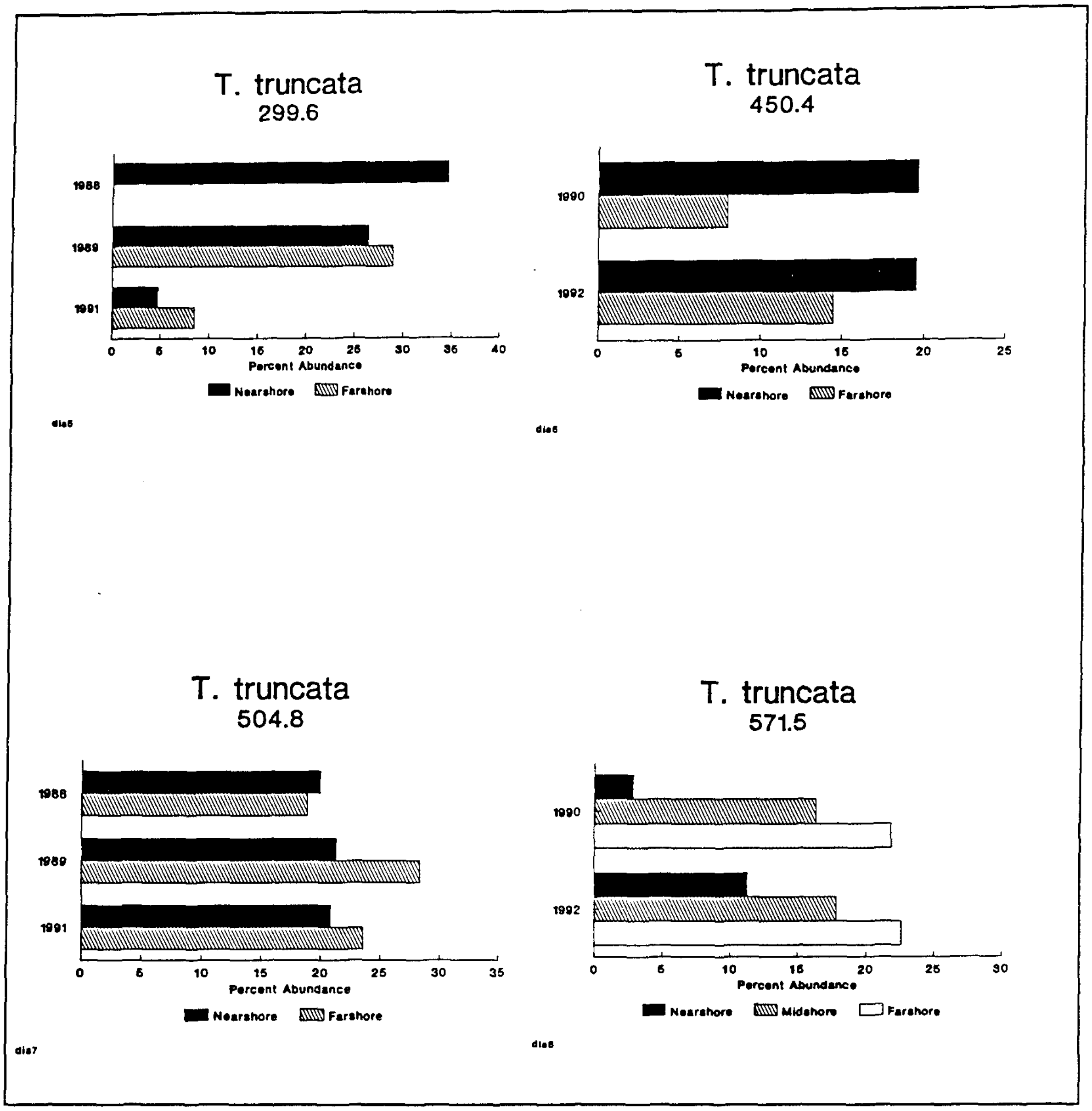
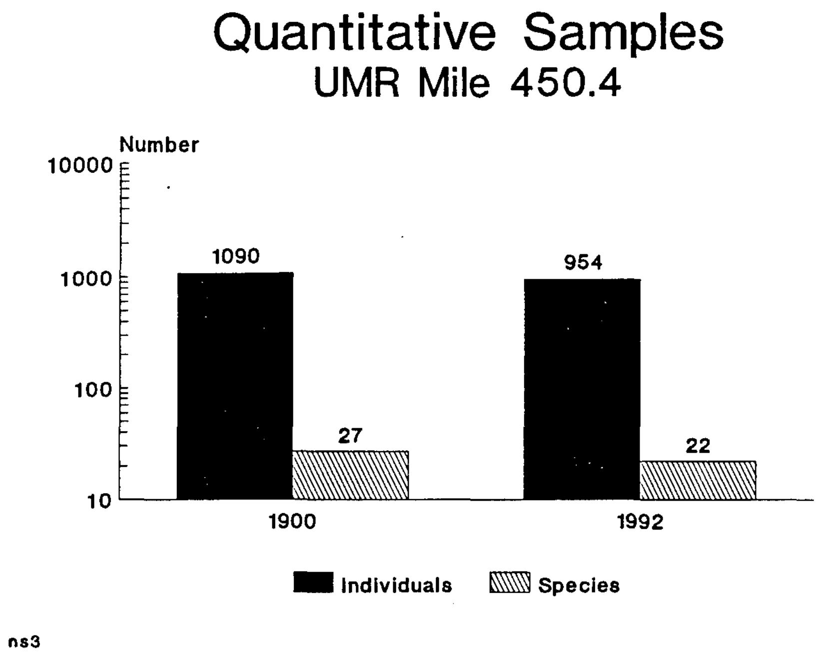


Figure 35. Percent abundance of *Truncilla truncata* at UMR Miles 299.6, 450.4, 504.8, and 571.5, 1988-1992



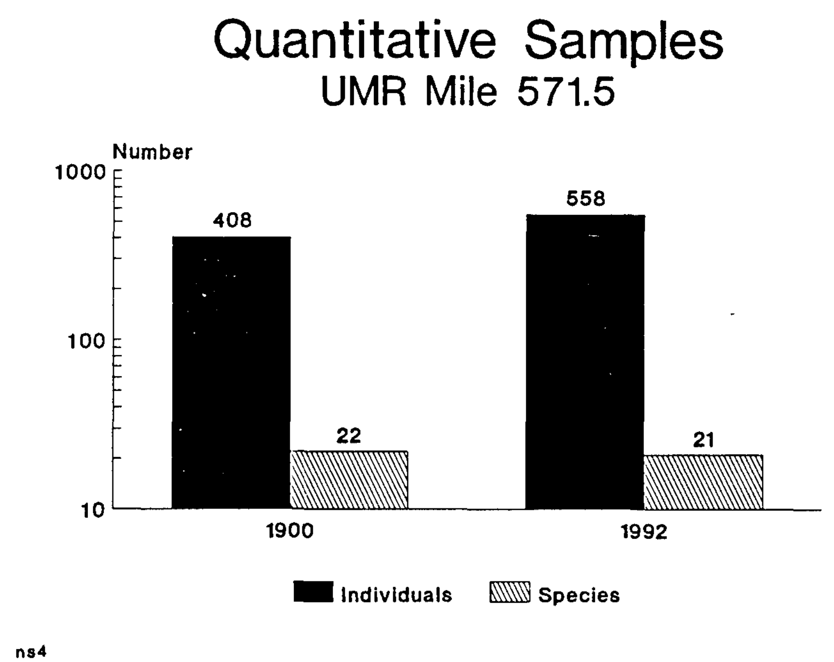
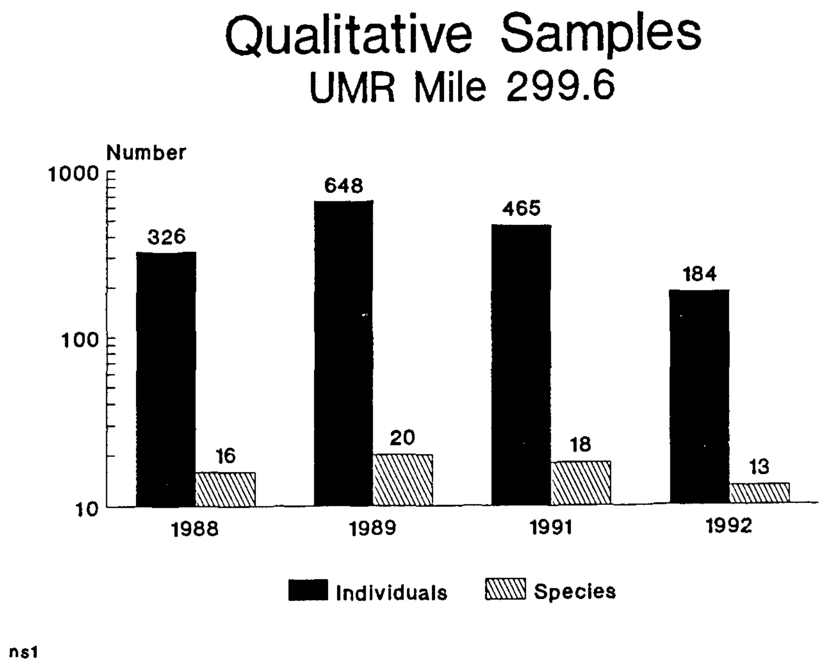


Figure 36. Total number of species and individuals collected using quantitative methods at UMR Miles 450.4 and 571.5, 1990-1992



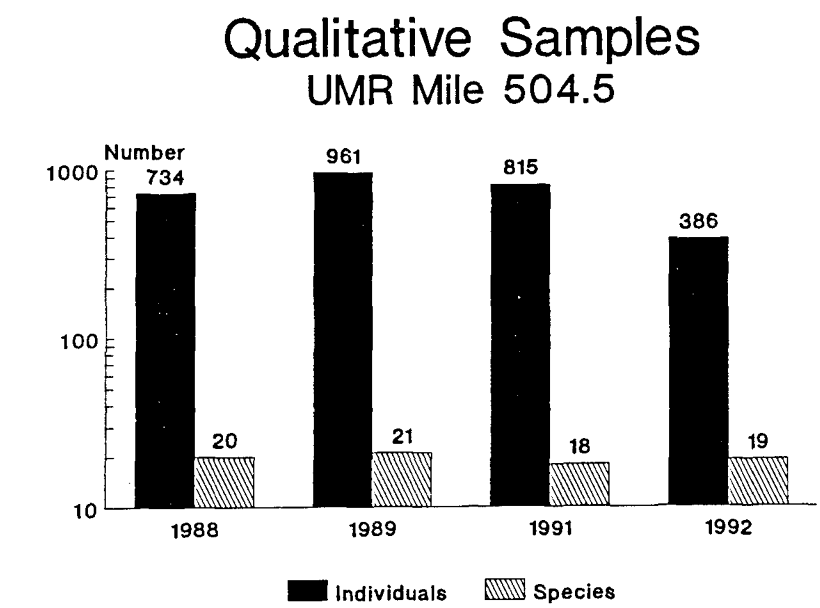


Figure 37. Total number of species and individuals collected using qualitative methods at UMR Miles 299.6 and 504.8, 1988-1992

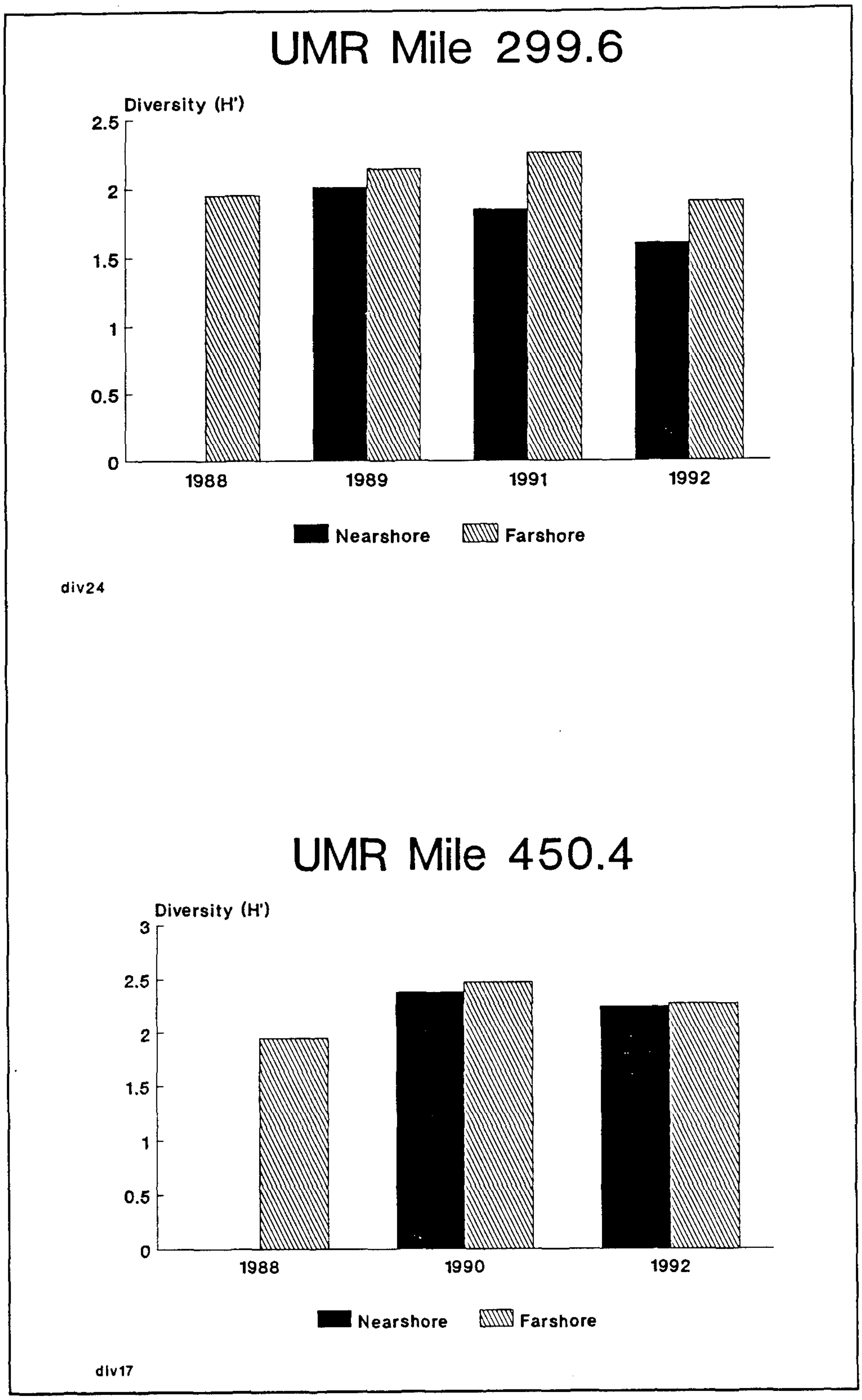


Figure 38. Changes in species diversity (H') for mussels collected at UMR Mile 299.6 and 450.4, 1988-92

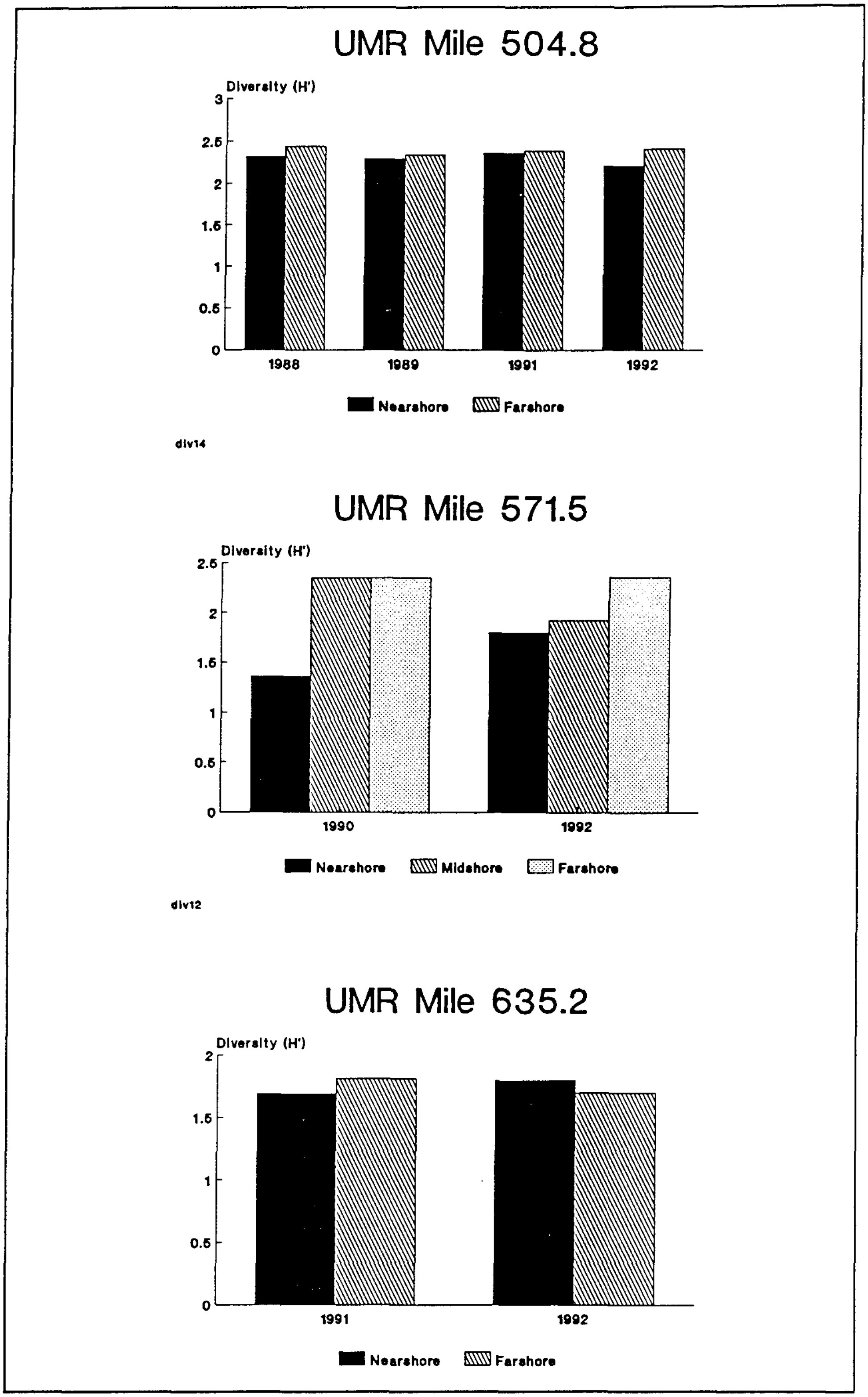
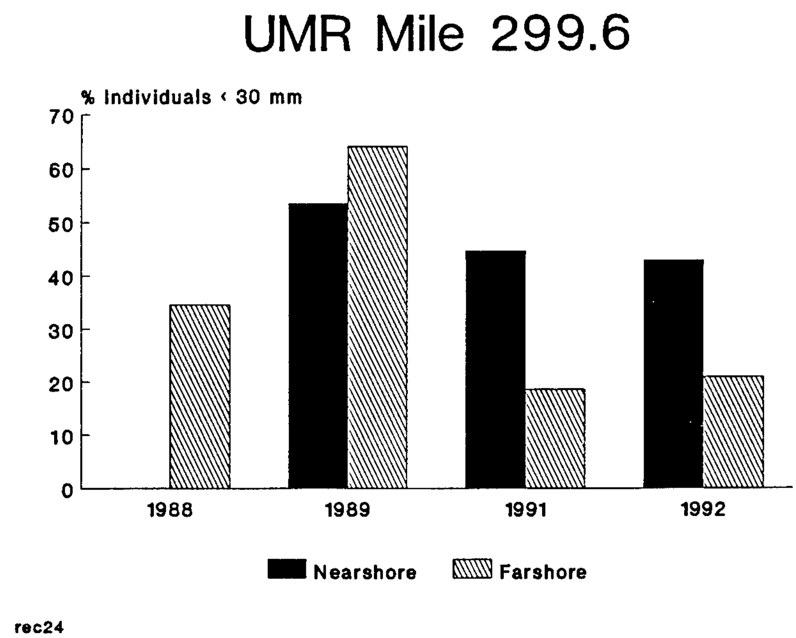


Figure 39. Changes in species diversity (H') for mussels collected at UMR Mile 504.8, 571.5, and 635.2, 1988-92



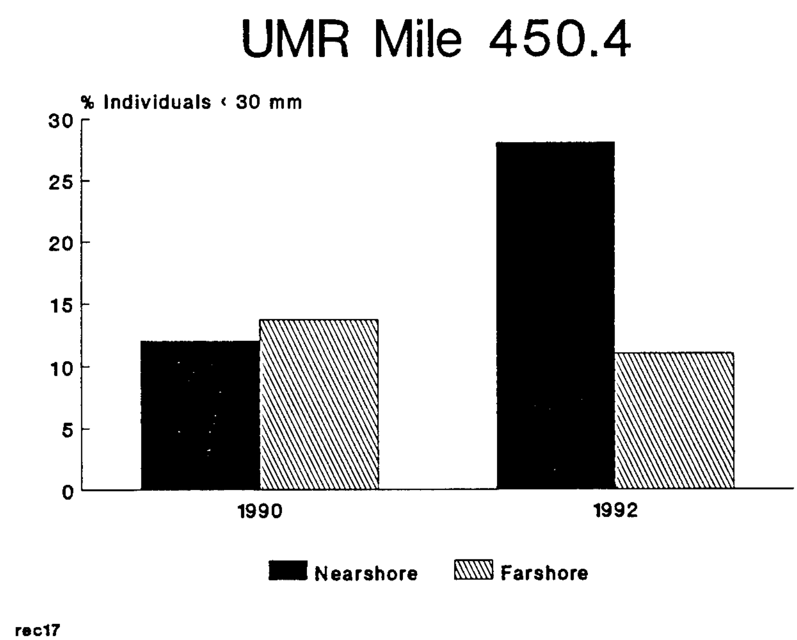


Figure 40. Evidence of recent recruitment (percent individuals less than 30 mm total shell length) for mussels collected at UMR Mile 299.6 and 450.4, 1988-92

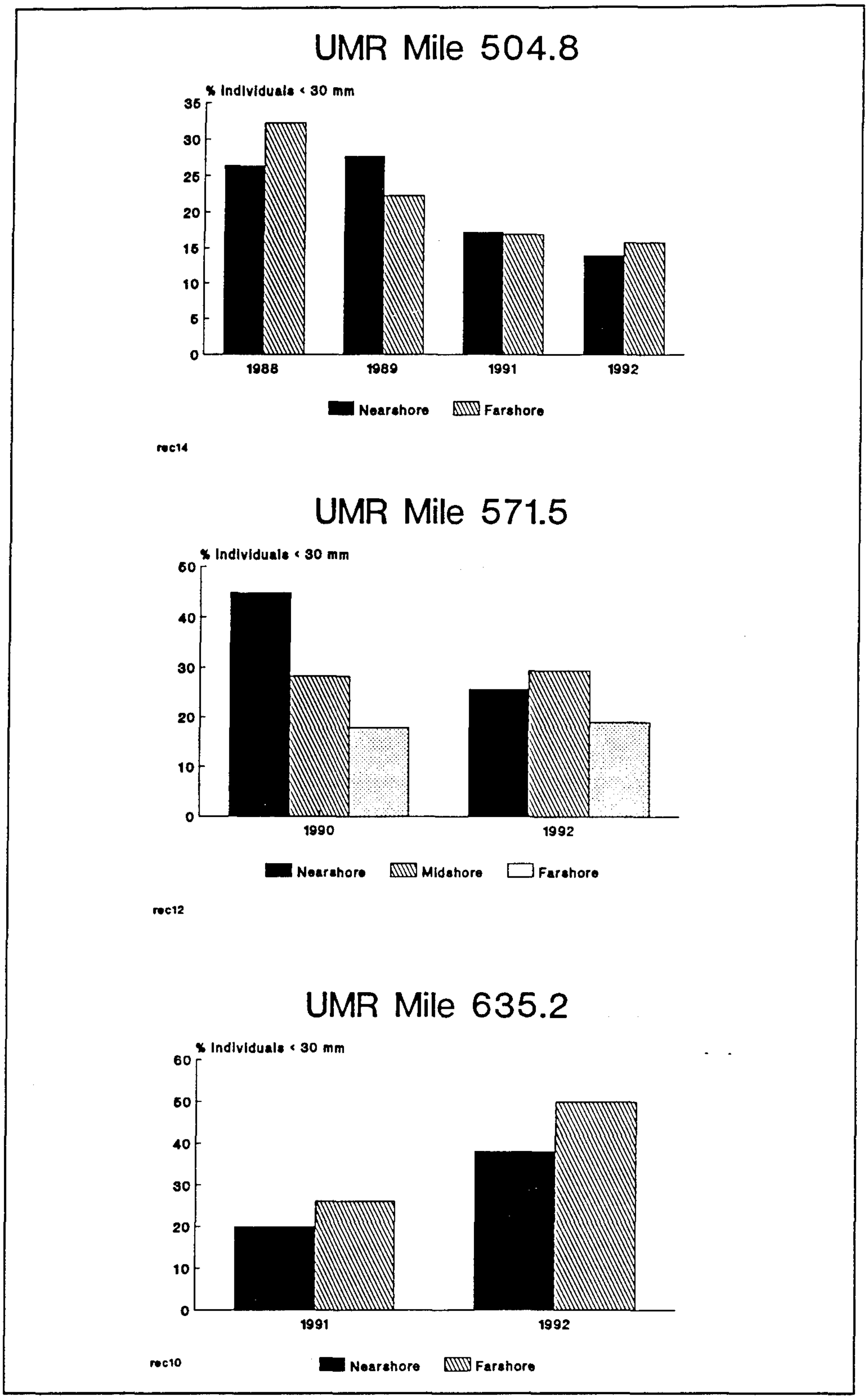


Figure 41. Evidence of recent recruitment (percent individuals less than 30 mm total shell length) for mussels collected at UMR Mile 504.8, 571.5, and 635.2, 1988-92

Table 1

Summary of Biological and Physical Studies Conducted for the Navigation Traffic Effects Study, Upper Mississippi River, 1988-94. (This report describes studies conducted in 1992)

Pool	RM	Year						
		88	89	90	91	92	93	94
24	299.6	Qual Quant	Qual Quant		Qual Quant Growth----- Physical	------------	Qual Quant -----------	------------
17	450.4	Qual Quant		Qual Quant Growth-- Physical	------------	Qual Quant ------------	----------	Qual Quant ------------
14	504.8	Qual Quant	Qual Quant Growth----- Physical	-------------	Qual Quant -------------- Physical	------------	Qual Quant -----------	------------
12	571.5	ND	Qual	Qual Quant Growth--- Physical	---------------	Qual Quant ------------	----------	Qual Quant ------------
10 (MC)	635.2	Qual	Qual Quant Growth---- Physical	-------------	Quant Qual -------------- Physical	------------	Quant Qual ----------	------------

Notes: Quant - Quantitative samples.
Qual - Qualitative samples.
Growth - Marked mussels are placed for analysis of rate of growth.
Physical - Measures of water velocity and total suspended solids following passage of a commercial vessel.
MC - Main Channel.
Precise river miles can differ in previous reports since exact location can vary slightly (0.1 to 0.4 miles) each year.
ND - No Data.
Dashed Lines (--) indicate that growth studies continue from year-to-year.

Table 2
Summary of Bivalve Collections Using Qualitative and Quantitative Methods in the UMR, 1988-92

Pool	RM	Year	No. of Quantitative Samples	No. of Qualitative Samples	No. of Bucket Samples
24	299.6	1988	10	18	--
		1989	60	42	--
		1990	--	--	--
		1991	60	24	--
		1992	--	12	10
17	450.4	1988	20	27	--
		1989	--	--	--
		1990	60	32	--
		1991	--	--	--
		1992	60	24	--
14	504.8	1988	20	27	--
		1989	60	59	--
		1990	--	--	--
		1991	60	48	--
		1992	--	24	40
12	571.5	1988	--	--	--
		1989	--	33	--
		1990	60	36	--
		1991	--	--	--
		1992	60	36	--
10	635.2	1988	--	43	--
		1989	40	14	--
		1990	--	--	--
		1991	60	48	--
		1992	--	24	40

Note: Dashed lines (--) indicates no data.

Table 3
Quantitative and Qualitative Mussel Collections in the UMR, 1992

River Mile	Subsite	Distance to Shore, ft	Depth, ft	Qualitative Samples	Quantitative Samples	Bucket Samples
8 July 1992, Pool 24						
299.6R	1	85	12	--	--	5
299.6R	1	200	20	12	--	5
9-11 July 1992 Pool 17						
450.4R	1-3	85	19	12	30	--
450.4R	4-6	140	20	12	30	--
12 July 1992, Pool 14						
504.8R	1-3	100	9	12	--	20
504.8R	4-6	300	12	12	--	20
13-15 July 1992, Pool 12						
571.5R	1-2	70	9	12	20	--
571.5R	3-4	140	12	12	20	--
571.5R	5-6	220	15	12	20	--
19-20 July 1991, Pool 10						
635.2R	1	7 5	21	12	--	20
635.2R	2	120	21	12	--	20

Note: Dashed line (--) indicates no data.

Table 4
Percent Abundance and Percent Occurrence of Freshwater Mussels Collected Using Qualitative Techniques in the Upper Mississippi River, July 1992. (Samples were collected at mussel beds in Pool 24 (RM 299.6), Pool 17 (RM 450.4), Pool 14 (RM 504.8), Pool 12 (571.5), and the Main Channel of Pool 10 (RM 635.2))

Species	Abundance	Occurrence
Amblema plicata plicata (Say, 1817)	39.79	85.00
Quadrula pustulosa pustulosa (Lea, 1831)	9.05	54.17
Truncilla truncata (Lea, 1860)	7.77	50.00
Obliquaria reflexa Rafinesque, 1820	7.25	50.00
Quadrula quadrula (Rafinesque, 1820)	7.13	40.83
Ellipsaria lineolata (Rafinesque, 1820)	6.90	41.67
Megalonaias nervosa (Rafinesque, 1820)	4.58	30.00
Fusconaia flava (Rafinesque, 1820)	2.73	34.17
Lampsilis ovata (Say, 1817)	2.67	31.67
Leptodea fragilis (Rafinesque, 1820)	2.67	24.17
Obovaria olivaria (Rafinesque, 1820)	2.44	26.67
Ligumia recta (Lamarck, 1819)	1.33	11.67
Potamilus alatus (Say, 1817)	0.81	14.17
Quadrula metanevra (Rafinesque, 1820)	1.04	12.50
Anodonta grandis (Say, 1829)	0.75	8.33
Arcidens confragosus (Say, 1829)	0.64	9.17
Strophitus undulatus (Say, 1817)	0.58	8.33
Quadrula nodulata (Rafinesque, 1817)	0.46	5.00
Actinonaias ligamentina (Larmack 1819)	0.46	6.67
Lasmigona complanata (Barnes, 1823)	0.35	5.00
Lampsilis higginsi (Lea, 1857)	0.23	3.33
Truncilla donaciformis (I. Lea, 1828)	0.12	0.83
Anodonta imbecillis Say, 1829	0.12	1.67
Elliptio dilatata (Rafinesque, 1820)	0.06	1.67
Potamilus ohiensis (Rafinesque, 1820)	0.06	0.83

Total individuals	1,724
Total species	25
Total samples	120

Table 5
Summary Statistics for Unionids (average density, individuals/sq m and standard error, SE) Collected in 0.25-m^2 Quadrats at RM 450.4R, Pool 17, UMR, 1992. (Means with the same superscript are not significantly different ($p > 0.05$))

Subsite	Distance to Shore, ft	Density	SE
1	85	87.6^{a}	7.26
2	85	86.0^{a}	6.56
3	85	55.6^{b}	4.97
Total		76.4	4.46
1	140	36.0^{c}	6.61
2	140	28.8^{c}	3.25
3	140	87.6^{a}	6.01
Total		50.8	5.74

Analysis of Variance:

	F	PR>F
Between sites	12.4	0.0009

Table 6
Summary Statistics for Unionids (average density, individuals/sq m, and standard error, SE) Collected in 0.25-m^2 Quadrats at RM 571.5R, Pool 12, UMR, 1992. (Means with the same superscript are not significantly different ($p > 0.05$))

Subsite	Distance to Shore, ft	Density	SE
1	70	42.8^{ab}	5.78.
2	70	49.2^{a}	4.73
Total		46.0	3.02
1	140	21.6^{c}	1.70
2	140	30.0^{bc}	4.05
Total		25.8	1.92
1	220	41.2^{ab}	3.91
2	220	38.4^{ab}	4.66
Total		39.8	2.43

Analysis of Variance:

	F	PR>F
Among sites	0.79	0.37

Table 7
Percent Abundance and Selected Community Descriptors for Bivalve Data Collected in the Upper Mississippi River, 1992. (Samples were obtained by having divers collect a specific number of sediment samples using 20-ℓ buckets)

	RM 299		RM 505		RM 635		
Species	**Near-Shore**	**Far-Shore**	**Near-Shore**	**Far-Shore**	**Near-Shore**	**Far-Shore**	**Total**
A. p. plicata	28.57	17.44	28.00	8.50	49.17	55.39	33.35
T. truncata	19.05	26.74	13.75	23.50	20.27	13.78	18.17
O. reflexa	33.33	27.91	17.00	11.00	3.99	4.51	10.77
Q. p. pustulosa	0.00	2.33	13.50	12.75	1.66	0.75	7.16
Q. quadrula	0.00	1.16	5.75	10.75	1.99	3.01	5.29
M. nervosa	0.00	2.33	3.00	6.75	4.65	4.76	4.60
E. lineolata	4.76	12.79	4.50	5.75	0.00	1.00	3.55
L. fragilis	0.00	1.16	2.75	3.50	3.65	3.51	3.17
F. flava	0.00	1.16	3.50	1.25	4.32	2.51	2.68
O. olivaria	4.76	0.00	1.00	7.50	0.33	0.50	2.36
T. donaciformis	4.76	2.33	1.50	1.75	1.66	2.51	1.93
P. alatus	0.00	0.00	0.25	2.50	1.00	1.25	1.18
L. ovata	0.00	1.16	1.00	1.00	1.99	1.00	1.18
A. imbecillis	0.00	0.00	0.25	0.50	0.33	2.26	0.81
Q. nodulata	0.00	1.16	1.50	0.25	0.33	0.00	0.56
E. dilatata	0.00	0.00	0.00	0.00	0.33	1.75	0.50
A. grandis	4.76	0.00	0.25	0.25	0.66	0.75	0.50
P. laevissima	0.00	0.00	0.00	0.50	0.00	0.00	0.12
A. confragosus	0.00	0.00	0.50	0.75	0.33	0.00	0.37
S. undulatus	0.00	0.00	0.25	0.00	1.00	0.50	0.37
Q. metanevra	0.00	2.33	0.75	0.25	0.00	0.00	0.37
L. higginsi	0.00	0.00	0.50	0.00	1.00	0.00	0.31
L. recta	0.00	0.00	0.25	0.00	1.00	0.25	0.31
L. complanata	0.00	0.00	0.00	0.75	0.00	0.00	0.19
A. ligamentina	0.00	0.00	0.00	0.25	0.00	0.00	0.06
C. fluminea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T. parvus	0.00	0.00	0.25	0.00	0.00	0.00	0.06
P. sintoxia	0.00	0.00	0.00	0.00	0.33	0.00	0.06
Total individuals	21	86	400	400	301	399	1,626
Total samples	5	5	20	20	20	20	
Total species	7	13	22	21	21	18	
Dominance	0.2	0.2	0.2	0.1	0.3	0.3	
Species diversity	1.6	1.9	2.2	2.4	1.8	1.7	
Evenness	0.8	0.7	0.7	0.8	0.6	0.6	
% Individuals < 30 mm	42.8	20.9	14.0	15.8	17.9	28.1	
% Species < 30 mm	57.1	61.5	45.4	38.1	38.1	50.0	

Table 8
Number of Fresh Dead Mussels (Tissue Present) in Quantitative Samples Collected at RM 450.4 and 571.5, UMR, July, 1992

Location	Subsite 1	Subsite 2	Subsite 3
RM 450.4			
85 ft from RDB	0	0	0
140 ft from RDB	0	0	0
RM 571.5			
70 ft from RDB	0	1	--
140 ft from RDB	0	0	--
220 ft from RDB	0	0	--

Note: Dashed line (--) means that no data were collected.

Table 9
Numbers of *Lampsilis higginsi* Taken in Qualitative and Quantitative Samples in the UMR, 1988-92

Location	Quantitative			Qualitative		
	Total Mussels	*L. higginsi* Total	*L. higginsi* %	Total Mussels	*L. higginsi* Total	*L. higginsi* %
Pool 24 (RM 299.6)						
1988	78	0	0.00	326	0	0.00
1989	1,143	0	0.00	648	0	0.00
1991	301	0	0.00	465	0	0.00
1992	107	0	0.00	184	0	0.00
Pool 17 (RM 450.4)						
1988	1,176	0	0.00	567	1	0.18
1990	651	0	0.00	506	0	0.00
1992	954	0	0.00	402	0	0.00
Pool 14 (RM 504.8)						
1988	253	1	0.40	734	8	1.09
1989	1,131	1	0.09	961	5	0.52
1991	1,247	6	0.49	815	6	0.74
1992	800	2	0.25	386	3	0.78
Pool 12 (RM 571.5)						
1989	--	--	--	98	0	0.00
1990	408	5	1.22	518	5	0.98
1992	558	1	0.18	376	0	0.00
Pool 10 (RM 635.2)						
1988	845	2	0.24	699	12	1.72
1989	1,616	11	0.68	212	0	0.00
1991	861	2	0.23	690	4	0.58
1992	700	3	0.43	376	1	0.27

Appendix A
Freshwater Bivalves Collected in the Upper Mississippi River (UMR) in 1992 Using Qualitative Techniques

Table A1
Percent Abundance of Bivalve Species Collected Using Qualitative Techniques at Five Mussel Beds in the Upper Mississippi River, 1992

Species	River Mile					Total
	299.6	450.4	504.5	571.5	635.2	
A. p. plicata	22.28	26.12	29.27	40.43	73.14	39.79
Q. p. pustulosa	3.26	16.17	16.32	3.99	1.86	9.05
T. truncata	15.22	8.46	11.66	4.52	2.66	7.77
O. reflexa	24.46	3.98	8.55	7.45	0.80	7.25
E. lineolata	18.48	18.41	2.85	1.06	0.00	7.13
Q. quadrula	3.26	1.99	10.36	13.30	3.99	6.90
M. nervosa	2.72	4.73	4.40	6.38	3.72	4.58
F. flava	1.09	1.49	3.89	5.05	1.33	2.73
L. fragilis	0.00	2.24	2.07	4.26	3.46	2.67
L. ovata	2.17	1.74	1.81	4.79	2.66	2.67
O. olivaria	5.43	3.73	3.11	1.33	0.00	2.44
L. recta	0.00	1.24	1.55	2.66	0.53	1.33
P. alatus	0.00	0.00	0.78	1.60	1.33	0.81
Q. metanevra	0.54	2.99	0.78	0.00	0.53	1.04
A. grandis	0.00	1.00	0.52	0.53	1.33	0.75
A. confragosus	0.00	1.00	0.78	1.06	0.00	0.64
S. undulatus	0.00	1.00	0.00	0.27	1.33	0.58
A. ligamentina	0.54	1.74	0.00	0.00	0.00	0.46
L. complanata	0.00	1.49	0.26	0.27	0.00	0.46
Q. nodulata	0.54	0.50	0.26	0.53	0.00	0.35
L. higginsi	0.00	0.00	0.78	0.00	0.27	0.23
E. dilatata	0.00	0.00	0.00	0.00	0.53	0.12
T. donaciformis	0.00	0.00	0.00	0.27	0.27	0.12
A. imbecillis	0.00	0.00	0.00	0.27	0.00	0.06
P. laevissima	0.00	0.00	0.00	0.00	0.27	0.06
Total individuals	184	402	386	376	376	1,724

Table A2
Percent Occurrence of Bivalve Species Collected Using Qualitative Techniques at Five Mussel Beds in the Upper Mississippi River, 1992

Species	River Mile					Total
	299.6	450.4	504.5	571.5	635.2	
A. p. plicata	75.00	91.67	100.00	63.89	100.00	85.00
Q. quadrula	41.67	29.17	79.17	58.33	54.17	54.17
T. truncata	75.00	62.50	79.17	27.78	29.17	50.00
Q. p. pustulosa	33.33	87.50	83.33	25.00	25.00	50.00
O. reflexa	91.67	37.50	62.50	30.56	12.50	40.83
M. nervosa	25.00	54.17	41.67	38.89	41.67	41.67
F. flava	16.67	20.83	45.83	36.11	20.83	30.00
E. lineolata	75.00	79.17	37.50	11.11	0.00	34.17
L. ovata	33.33	25.00	20.83	36.11	41.67	31.67
L. fragilis	0.00	29.17	20.83	27.78	29.17	24.17
O. olivaria	75.00	45.83	33.33	11.11	0.00	26.67
P. alatus	0.00	0.00	12.50	16.67	20.83	11.67
L. recta	0.00	16.67	16.67	19.44	8.33	14.17
Q. metanevra	8.33	37.50	12.50	0.00	8.33	12.50
A. confragosus	0.00	12.50	12.50	11.11	0.00	8.33
A. grandis	0.00	12.50	8.33	5.56	16.67	9.17
S. undulatus	0.00	16.67	0.00	2.78	20.83	8.33
Q. nodulata	8.33	8.33	4.17	5.56	0.00	5.00
A. ligamentina	8.33	29.17	0.00	0.00	0.00	6.67
L. complanata	0.00	16.67	4.17	2.78	0.00	5.00
L. higginsi	0.00	0.00	12.50	0.00	4.17	3.33
A. imbecillis	0.00	0.00	0.00	2.78	0.00	0.83
E. dilatata	0.00	0.00	0.00	0.00	8.33	1.67
T. donaciformis	0.00	0.00	0.00	2.78	4.17	1.67
P. laevissima	0.00	0.00	0.00	0.00	4.17	0.83
Total Samples	12	24	24	36	24	120

Appendix B
Freshwater Bivalves Collected in the Upper Mississippi River (UMR) in 1992 Using Quantitative Techniques

Table B1
Percent Abundance of Bivalve Species Collected Using Quantitative Methods (0.25-sq m quadrats) at Three Nearshore Sites, RM 450.4, Upper Mississippi River, 1992

Species	Site 1	Site 2	Site 3	Total
Q. p. pustulosa	21.00	21.40	18.71	20.59
T. truncata	25.11	19.53	10.79	19.55
A. p. plicata	21.46	16.28	18.71	18.85
E. lineolata	12.33	15.35	16.55	14.49
O. reflexa	6.85	4.19	2.16	4.71
Q. quadrula	2.74	4.65	5.04	4.01
M. nervosa	0.91	3.72	7.19	3.49
T. donaciformis	2.28	2.79	4.32	2.97
F. flava	2.74	1.40	1.44	1.92
L. fragilis	0.00	1.40	5.04	1.75
O. olivaria	1.37	1.86	1.44	1.57
A. grandis	0.00	2.79	1.44	1.40
Q. metanevra	0.91	1.86	1.44	1.40
L. ovata	0.00	0.93	2.88	1.05
A. ligamentina	0.00	0.93	1.44	0.70
P. alatus	0.00	0.93	0.00	0.35
A. confragosus	0.91	0.00	0.00	0.35
A. imbecillis	0.00	0.00	0.72	0.17
L. recta	0.46	0.00	0.00	0.17
L. complanata	0.46	0.00	0.00	0.17
S. undulatus	0.46	0.00	0.00	0.17
C. monodonta	0.00	0.00	0.72	0.17
Total individuals	219	215	139	573
Total species	15	16	17	22
Dominance	0.17	0.14	0.12	0.14
Diversity	1.99	2.23	2.35	2.24
Evenness	0.47	0.80	0.83	0.72
% Individuals < 30 mm	32.87	26.04	23.74	28.10
% Species < 30 mm	53.33	50.00	52.94	40.91

Table B2
Percent Occurrence of Bivalve Species Collected Using Quantitative Techniques (0.25-sq m quadrats) at Three Nearshore Sites, RM 450.4, Upper Mississippi River, 1992

Species	Site 1	Site 2	Site 3	Total
T. truncata	100.00	100.00	90.00	96.67
A. p. plicata	80.00	100.00	100.00	93.33
E. lineolata	90.00	100.00	90.00	93.33
Q. p. pustulosa	100.00	90.00	80.00	90.00
Q. quadrula	50.00	60.00	50.00	53.33
M. nervosa	10.00	70.00	80.00	53.33
O. reflexa	70.00	60.00	30.00	53.33
T. donaciformis	40.00	40.00	30.00	36.67
L. fragilis	0.00	30.00	50.00	26.67
F. flava	0.00	20.00	20.00	26.67
O. olivaria	30.00	30.00	20.00	26.67
A. grandis	0.00	50.00	10.00	20.00
Q. metanevra	20.00	20.00	20.00	20.00
L. ovata	0.00	20.00	40.00	20.00
A. ligamentina	0.00	20.00	20.00	13.33
P. alatus	0.00	20.00	0.00	6.67
A. confragosus	20.00	0.00	0.00	6.67
A. imbecillis	0.00	0.00	10.00	3.33
L. recta	10.00	0.00	0.00	3.33
S. undulatus	10.00	0.00	0.00	3.33
L. complanata	10.00	0.00	0.00	3.33
C. monodonta	0.00	0.00	10.00	3.33
Total samples	10	10	10	30

Table B3
Percent Occurrence of Bivalve Species Collected Using Quantitative Techniques (0.25-sq m quadrats) at Three Farshore Sites, RM 450.4, Upper Mississippi River, 1992

Species	Site 1	Site 2	Site 3	Total
Q. p. pustulosa	28.89	26.39	22.83	24.93
A. p. plicata	23.33	16.67	15.53	17.59
T. truncata	11.11	8.33	17.81	14.44
E. lineolata	11.11	16.67	11.42	12.34
O. reflexa	3.33	5.56	8.68	6.82
O. olivaria	4.44	6.94	3.20	4.20
Q. metanevra	1.11	2.78	5.48	3.94
M. nervosa	5.56	2.78	2.74	3.41
T. donaciformis	3.33	2.78	3.65	3.41
L. ovata	2.22	4.17	0.91	1.84
L. fragilis	1.11	0.00	1.83	1.31
A. ligamentina	1.11	0.00	1.83	1.31
S. undulatus	2.22	0.00	1.37	1.31
Q. quadrula	0.00	2.78	0.91	1.05
F. flava	1.11	2.78	0.46	1.05
A. grandis	0.00	0.00	0.46	0.26
L. recta	0.00	0.00	0.46	0.26
A. imbecillis	0.00	1.39	0.00	0.26
A. confragosus	0.00	0.00	0.46	0.26
Total individuals	90	72	219	381
Total species	14	13	18	19
Dominance	0.16	0.13	0.13	0.14
Diversity	2.08	2.19	2.27	2.27
Evenness	0.78	0.85	0.79	0.77
% Individuals < 30 mm	36.67	29.17	36.99	11.03
% Species < 30 mm	42.86	53.85	38.89	45.45

Table B4
Percent Occurrence of Bivalve Species Collected Using Quantitative Techniques (0.25-sq m quadrats) at Three Farshore Sites, RM 450.4, Upper Mississippi River, 1992

Species	Site 1	Site 2	Site 3	Total
Q. p. pustulosa	80.00	90.00	100.00	90.00
A. p. plicata	80.00	80.00	90.00	83.33
E. lineolata	60.00	60.00	100.00	73.33
T. truncata	50.00	50.00	100.00	66.67
O. reflexa	30.00	20.00	90.00	46.67
O. olivaria	30.00	50.00	50.00	43.33
Q. metanevra	10.00	20.00	80.00	36.67
T. donaciformis	20.00	20.00	70.00	36.67
M. nervosa	40.00	20.00	30.00	30.00
L. ovata	20.00	30.00	20.00	23.33
S. undulatus	20.00	0.00	30.00	16.67
Q. quadrula	0.00	20.00	20.00	13.33
A. ligamentina	10.00	0.00	30.00	13.33
F. flava	10.00	20.00	10.00	13.33
L. fragilis	10.00	0.00	30.00	13.33
A. grandis	0.00	0.00	10.00	3.33
L. recta	0.00	0.00	10.00	3.33
A. imbecillis	0.00	10.00	0.00	3.33
A. confragosus	0.00	0.00	10.00	3.33
Total Samples	10	10	10	30

Table B5
Percent Abundance and Percent Occurrence of Bivalves Collected Using Quantitative Techniques (0.25-sq m quadrats) at Two Nearshore Subsites, Upper Mississippi River Mile 571.5, July 1992

Species	1	2	Total	1	2	Total
A. p. plicata	48.60	41.46	44.78	100.00	100.00	100.00
O. reflexa	19.63	22.76	21.30	90.00	90.00	90.00
T. truncata	10.28	12.20	11.30	50.00	80.00	65.00
Q. quadrula	7.48	4.07	5.65	70.00	40.00	55.00
L. fragilis	1.87	4.88	3.48	20.00	40.00	30.00
F. flava	2.80	1.63	2.17	20.00	20.00	20.00
T. donaciformis	0.93	3.25	2.17	10.00	40.00	25.00
A. grandis	2.80	0.81	1.74	30.00	10.00	20.00
L. recta	1.87	0.81	1.30	20.00	10.00	15.00
Q. p. pustulosa	0.93	1.63	1.30	10.00	20.00	15.00
Q. nodulata	0.93	0.81	0.87	10.00	10.00	10.00
E. lineolata	0.00	1.63	0.87	0.00	20.00	10.00
P. alatus	0.93	0.81	0.87	10.00	10.00	10.00
L. higginsi	0.00	0.81	0.43	0.00	10.00	5.00
A. imbecillis	0.00	0.81	0.43	0.00	10.00	5.00
M. nervosa	0.00	0.81	0.43	0.00	10.00	5.00
O. olivaria	0.00	0.81	0.43	0.00	10.00	5.00
L. ovata	0.93	0.00	0.43	10.00	0.00	5.00
Total individuals	107	123	230			
Total samples	10	10	20			
Total species	13	17	18			
Dominance	0.29	0.24	0.26			
Species diversity	1.66	1.86	1.80			
Evenness	0.65	0.66	0.62			
% Individuals < 30 mm	23.36	27.64	25.65			
% Species < 30 mm	61.53	23.53	44.44			

Table B6
Percent Abundance and Percent Occurrence of Bivalves Collected Using Quantitative Techniques (0.25-sq m quadrats) at Two Midshore Subsites, Upper Mississippi River Mile 571.5, July 1992

Species	1	2	Total	1	2	Total
A. p. plicata	31.48	40.00	36.43	100.0	100.00	100.00
O. reflexa	29.63	13.33	20.16	80.00	70.00	75.00
T. truncata	14.81	20.00	17.83	40.00	80.00	60.00
Q. Quadrula	3.70	8.00	6.20	20.00	30.00	25.00
M. nervosa	5.56	4.00	4.65	30.00	20.00	25.00
A. grandis	1.85	2.67	2.33	10.00	20.00	15.00
F. flava	3.70	1.33	2.33	20.00	10.00	15.00
L. fragilis	3.70	1.33	2.33	20.00	10.00	15.00
E. lineolata	0.00	2.67	1.55	0.00	20.00	10.00
Q. p. pustulosa	1.85	1.33	1.55	10.00	10.00	10.00
A. imbecillis	1.85	1.33	1.55	10.00	10.00	10.00
T. donaciformis	0.00	1.33	0.78	0.00	10.00	5.00
O. olivaria	0.00	1.33	0.78	0.00	10.00	5.00
L. recta	0.00	1.33	0.78	0.00	10.00	5.00
L. ovata	1.85	0.00	0.78	10.00	0.00	5.00
Total individuals	54	75	129			
Total samples	10	10	10			
Total species	11	14	15			
Dominance	0.20	0.22	0.21			
Species diversity	1.83	1.88	1.92			
Evenness	0.76	0.71	0.71			
% Individuals < 30 mm	16.67	38.67	29.46			
% Species < 30 mm	36.36	57.14	60.00			

Table B7
Percent Abundance and Percent Occurrence of Bivalves Collected Using Quantitative Techniques (0.25-sq m quadrats) at Two Farshore Subsites, Upper Mississippi River Mile 571.5, July 1992

Species	1	2	Total	1	2	Total
A. p. plicata	21.36	25.00	23.12	80.00	100.00	90.00
O. reflexa	11.65	10.42	11.06	80.00	50.00	65.00
T. truncata	19.42	26.04	22.61	90.00	90.00	90.00
Q. quadrula	10.68	4.17	7.54	60.00	30.00	45.00
M. nervosa	3.88	7.29	5.53	40.00	50.00	45.00
L. fragilis	6.80	3.13	5.03	60.00	20.00	40.00
E. lineolata	5.83	3.13	4.52	40.00	30.00	35.00
O. olivaria	1.94	5.21	3.52	10.00	40.00	25.00
F. flava	2.91	4.17	3.52	30.00	30.00	30.00
A. confragosus	3.88	1.04	2.51	30.00	10.00	20.00
I. ovata	2.91	1.04	2.01	30.00	10.00	20.00
L. recta	1.94	2.08	2.01	20.00	20.00	20.00
Q. p. pustulosa	1.94	2.08	2.01	20.00	20.00	20.00
A. imbecillis	1.94	1.04	1.51	20.00	10.00	15.00
S. undulatus	0.00	2.08	1.01	0.00	20.00	10.00
A. ligamentina	0.97	1.04	1.01	10.00	10.00	10.00
Q. nodulata	0.97	0.00	0.50	10.00	0.00	5.00
P. alatus	0.00	1.04	0.50	0.00	10.00	5.00
A. grandis	0.97	0.00	0.50	10.00	0.00	5.00
Total individuals	103	96	199			
Total samples	10	10	20			
Total species	17	17	19			
Dominance	0.11	0.15	0.13			
Species diversity	2.38	2.24	2.36			
Evenness	0.84	0.79	0.80			
% Individuals < 30 m	18.45	19.79	19.09			
% Species < 30 mm	29.41	23.53	31.58			

Table B8
Percent Abundance and Percent Occurrence of Bivalves Collected Using Quantitative Methods (0.25-sq m quadrats) at All Six Subsites Combined (Taken from Tables B5, B6, and B7), Upper Mississippi River Mile 571.5, July 1992

Species	Percent Abundance	Percent Occurrence
A. p. plicata	35.13	76.67
O. reflexa	17.38	60.00
T. truncata	16.85	63.33
Q. quadrula	6.45	36.67
L. fragilis	3.76	31.67
M. nervosa	3.23	36.67
F. flava	2.69	28.33
E. lineolata	2.33	28.33
Q. p. pustulosa	1.61	23.33
O. olivaria	1.61	23.33
A. grandis	1.43	20.00
L. recta	1.43	21.67
T. donaciformis	1.08	15.00
A. imbecillis	1.08	21.67
L. ovata	1.08	21.67
A. confragosus	0.90	20.00
P. alatus	0.54	15.00
Q. nodulata	0.54	15.00
A. ligamentina	0.36	16.67
S. undulatus	0.36	16.67
L. higginsi	0.18	13.33
Total individuals	558	
Total samples	60	
Total species	21	
Dominance	0.19	
Species diversity	2.12	
Evenness	0.71	
% Individuals < 30 mm	24.19	
% Species < 30 mm	52.38	

Appendix C
Length-Frequency Histograms for Bivalves Collected in the Upper Mississippi River (UMR) in 1992

```
Shell Length                                    Cum                 Cum
                                         Freq   Freq    Percent    Percent

    20  |                                    0      0      0.00       0.00
    22  |                                    0      0      0.00       0.00
    24  |                                    0      0      0.00       0.00
    26  |                                    0      0      0.00       0.00
    28  |**********                          1      1      4.76       4.76
    30  |**********                          1      2      4.76       9.52
    32  |**********                          1      3      4.76      14.29
    34  |*******************                 2      5      9.52      23.81
    36  |**********                          1      6      4.76      28.57
    38  |*****************************       3      9     14.29      42.86
    40  |*******************                 2     11      9.52      52.38
    42  |*******************                 2     13      9.52      61.90
    44  |*******************                 2     15      9.52      71.43
    46  |*****************************       3     18     14.29      85.71
    48  |*******************                 2     20      9.52      95.24
    50  |                                    0     20      0.00      95.24
    52  |                                    0     20      0.00      95.24
    54  |                                    0     20      0.00      95.24
    56  |                                    0     20      0.00      95.24
    58  |**********                          1     21      4.76     100.00
    60  |                                    0     21      0.00     100.00
    62  |                                    0     21      0.00     100.00
    64  |                                    0     21      0.00     100.00
        ----+---+---+---+---+---+---+-
            2   4   6   8  10  12  14

               Percentage
```

Figure C1. Shell length (mm) frequency histogram of *Amblema plicata plicata* in the UMR Mile 299.6 (Pool 24), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers fill ten 20-ℓ buckets of sediment

Shell Length		Freq	Cum Freq	Percent	Cum Percent
6		0	0	0.00	0.00
8		0	0	0.00	0.00
10	******	1	1	3.23	3.23
12	*************	2	3	6.45	9.68
14		0	3	0.00	9.68
16	******	1	4	3.23	12.90
18	******	1	5	3.23	16.13
20	*************	2	7	6.45	22.58
22	**************************	4	11	12.90	35.48
24	*******************	3	14	9.68	45.16
26		0	14	0.00	45.16
28		0	14	0.00	45.16
30	*************	2	16	6.45	51.61
32	*************	2	18	6.45	58.06
34	******	1	19	3.23	61.29
36	*************	2	21	6.45	67.74
38		0	21	0.00	67.74
40	*******************	3	24	9.68	77.42
42		0	24	0.00	77.42
44	*************	2	26	6.45	83.87
46	*************	2	28	6.45	90.32
48	*******************	3	31	9.68	100.00
50		0	31	0.00	100.00
52		0	31	0.00	100.00
54		0	31	0.00	100.00
56		0	31	0.00	100.00

```
----+---+---+---+---+---+--
    2   4   6   8   10  12
```

Percentage

Figure C2. Shell length (mm) frequency histogram of *Obliquaria reflexa* in the UMR Mile 299.6 (Pool 24), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers fill ten 20-ℓ buckets of sediment

Shell Length		Freq	Cum Freq	Percent	Cum Percent
8		0	0	0.00	0.00
10		0	0	0.00	0.00
12		0	0	0.00	0.00
14		0	0	0.00	0.00
16	****	1	1	3.70	3.70
18		0	1	0.00	3.70
20	****	1	2	3.70	7.41
22		0	2	0.00	7.41
24		0	2	0.00	7.41
26	****	1	3	3.70	11.11
28		0	3	0.00	11.11
30	****	1	4	3.70	14.81
32		0	4	0.00	14.81
34	****	1	5	3.70	18.52
36	**********************	6	11	22.22	40.74
38	*******	2	13	7.41	48.15
40	***********	3	16	11.11	59.26
42	**********************	6	22	22.22	81.48
44	*******	2	24	7.41	88.89
46	****	1	25	3.70	92.59
48	*******	2	27	7.41	100.00
50		0	27	0.00	100.00
52		0	27	0.00	100.00
54		0	27	0.00	100.00

```
-----+----+----+----+--
     5   10   15   20
```

Percentage

Figure C3. Shell length (mm) frequency histogram of *Truncilla truncata* in the UMR Mile 299.6 (Pool 24), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers fill ten 20-ℓ buckets of sediment

Shell Length		Freq	Cum Freq	Percent	Cum Percent
24		0	0	0.00	0.00
26	************	1	1	3.03	3.03
28		0	1	0.00	3.03
30		0	1	0.00	3.03
32		0	1	0.00	3.03
34		0	1	0.00	3.03
36		0	1	0.00	3.03
38		0	1	0.00	3.03
40		0	1	0.00	3.03
42		0	1	0.00	3.03
44		0	1	0.00	3.03
46		0	1	0.00	3.03
48		0	1	0.00	3.03
50		0	1	0.00	3.03
52		0	1	0.00	3.03
54		0	1	0.00	3.03
56		0	1	0.00	3.03
58		0	1	0.00	3.03
60		0	1	0.00	3.03
62	************	1	2	3.03	6.06
64		0	2	0.00	6.06
66		0	2	0.00	6.06
68		0	2	0.00	6.06
70		0	2	0.00	6.06
72		0	2	0.00	6.06
74		0	2	0.00	6.06
76		0	2	0.00	6.06
78	************	1	3	3.03	9.09
80	************************	2	5	6.06	15.15
82		0	5	0.00	15.15
84	************************************	3	8	9.09	24.24
86		0	8	0.00	24.24
88	************************	2	10	6.06	30.30
90	************	1	11	3.03	33.33
92	************************************	3	14	9.09	42.42
94	************************	2	16	6.06	48.48
96	************	1	17	3.03	51.52
98	************	1	18	3.03	54.55
100	************************	2	20	6.06	60.61
102	************************	2	22	6.06	66.67
104	************	1	23	3.03	69.70
106		0	23	0.00	69.70
108	************************	2	25	6.06	75.76
110	************	1	26	3.03	78.79
112	************	1	27	3.03	81.82
114		0	27	0.00	81.82
116	************************	2	29	6.06	87.88
118		0	29	0.00	87.88
120	************	1	30	3.03	90.91
122		0	30	0.00	90.91
124		0	30	0.00	90.91
126		0	30	0.00	90.91
128		0	30	0.00	90.91
130		0	30	0.00	90.91
132		0	30	0.00	90.91
134		0	30	0.00	90.91
136		0	30	0.00	90.91
138	************	1	31	3.03	93.94
140		0	31	0.00	93.94
142		0	31	0.00	93.94
144		0	31	0.00	93.94
146	************	1	32	3.03	96.97
148		0	32	0.00	96.97
150		0	32	0.00	96.97
152	************	1	33	3.03	100.00
154		0	33	0.00	100.00

```
----+----+----+----+----+----+----+----+----+
    1    2    3    4    5    6    7    8    9
```

Percentage

Figure C4. Shell length (mm) frequency histogram of *Megalonaias nervosa* in the UMR Mile 450.4 (Pool 17), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples

```
Shell Length                                      Cum                Cum
                                           Freq   Freq   Percent   Percent

   10 |                                       0      0      0.00      0.00
   12 |                                       0      0      0.00      0.00
   14 |                                       0      0      0.00      0.00
   16 |                                       0      0      0.00      0.00
   18 |***                                    1      1      0.57      0.57
   20 |***********                            4      5      2.29      2.86
   22 |********************                   7     12      4.00      6.86
   24 |*********                              3     15      1.71      8.57
   26 |**************************             9     24      5.14     13.71
   28 |**************                         5     29      2.86     16.57
   30 |**************************             9     38      5.14     21.71
   32 |********************                   7     45      4.00     25.71
   34 |***********                            4     49      2.29     28.00
   36 |*********                              3     52      1.71     29.71
   38 |**************                         5     57      2.86     32.57
   40 |*****************                      6     63      3.43     36.00
   42 |*****************                      6     69      3.43     39.43
   44 |*********                              3     72      1.71     41.14
   46 |**************                         5     77      2.86     44.00
   48 |******                                 2     79      1.14     45.14
   50 |***********                            4     83      2.29     47.43
   52 |*********                              3     86      1.71     49.14
   54 |***********                            4     90      2.29     51.43
   56 |***********                            4     94      2.29     53.71
   58 |*********                              3     97      1.71     55.43
   60 |                                       0     97      0.00     55.43
   62 |*********                              3    100      1.71     57.14
   64 |*********                              3    103      1.71     58.86
   66 |***********                            4    107      2.29     61.14
   68 |*****************                      6    113      3.43     64.57
   70 |***                                    1    114      0.57     65.14
   72 |***********************                8    122      4.57     69.71
   74 |********************                   7    129      4.00     73.71
   76 |***********************                8    137      4.57     78.29
   78 |**************                         5    142      2.86     81.14
   80 |**************************             9    151      5.14     86.29
   82 |***********************                8    159      4.57     90.86
   84 |***********                            4    163      2.29     93.14
   86 |***                                    1    164      0.57     93.71
   88 |******                                 2    166      1.14     94.86
   90 |***********                            4    170      2.29     97.14
   92 |*********                              3    173      1.71     98.86
   94 |                                       0    173      0.00     98.86
   96 |                                       0    173      0.00     98.86
   98 |******                                 2    175      1.14    100.00
  100 |                                       0    175      0.00    100.00
  102 |                                       0    175      0.00    100.00
  104 |                                       0    175      0.00    100.00
       ----+----+----+----+----+-
           1    2    3    4    5

           Percentage
```

Figure C5. Shell length (mm) frequency histogram of *Amblema plicata plicata* in the UMR Mile 450.4 (Pool 17), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples

Shell Length		Freq	Cum Freq	Percent	Cum Percent
16		0	0	0.00	0.00
18		0	0	0.00	0.00
20	***	2	2	1.54	1.54
22	********	5	7	3.85	5.38
24	*****	3	10	2.31	7.69
26		0	10	0.00	7.69
28	**	1	11	0.77	8.46
30		0	11	0.00	8.46
32	***	2	13	1.54	10.00
34		0	13	0.00	10.00
36	***	2	15	1.54	11.54
38	********	5	20	3.85	15.38
40	*********	6	26	4.62	20.00
42	***************	10	36	7.69	27.69
44	************	8	44	6.15	33.85
46	**********************	14	58	10.77	44.62
48	************	8	66	6.15	50.77
50	******	4	70	3.08	53.85
52	******	4	74	3.08	56.92
54	******	4	78	3.08	60.00
56	********************	13	91	10.00	70.00
58	*****	3	94	2.31	72.31
60	***********	7	101	5.38	77.69
62	***********	7	108	5.38	83.08
64	*****	3	111	2.31	85.38
66	*****	3	114	2.31	87.69
68	******	4	118	3.08	90.77
70	*****	3	121	2.31	93.08
72	*********	6	127	4.62	97.69
74		0	127	0.00	97.69
76	***	2	129	1.54	99.23
78	**	1	130	0.77	100.00
80		0	130	0.00	100.00
82		0	130	0.00	100.00
84		0	130	0.00	100.00
	2 4 6 8 10				
	Percentage				

Figure C6. Shell length (mm) frequency histogram of *Ellipsaria lineolata* in the UMR Mile 450.4 (Pool 17), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples

```
Shell Length                                                     Cum              Cum
                                                           Freq  Freq   Percent   Percent
           |
  0        |                                                  0     0     0.00      0.00
  2        |                                                  0     0     0.00      0.00
  4        |                                                  0     0     0.00      0.00
  6        |                                                  0     0     0.00      0.00
  8        |                                                  0     0     0.00      0.00
 10        |                                                  0     0     0.00      0.00
 12        |*******                                           1     1     3.70      3.70
 14        |                                                  0     1     0.00      3.70
 16        |                                                  0     1     0.00      3.70
 18        |*******                                           1     2     3.70      7.41
 20        |                                                  0     2     0.00      7.41
 22        |*******                                           1     3     3.70     11.11
 24        |*******                                           1     4     3.70     14.81
 26        |                                                  0     4     0.00     14.81
 28        |                                                  0     4     0.00     14.81
 30        |*******                                           1     5     3.70     18.52
 32        |*******                                           1     6     3.70     22.22
 34        |*******                                           1     7     3.70     25.93
 36        |                                                  0     7     0.00     25.93
 38        |*************************************             5    12    18.52     44.44
 40        |                                                  0    12     0.00     44.44
 42        |                                                  0    12     0.00     44.44
 44        |                                                  0    12     0.00     44.44
 46        |*******                                           1    13     3.70     48.15
 48        |*******                                           1    14     3.70     51.85
 50        |*******                                           1    15     3.70     55.56
 52        |*******                                           1    16     3.70     59.26
 54        |*******                                           1    17     3.70     62.96
 56        |*******                                           1    18     3.70     66.67
 58        |*******                                           1    19     3.70     70.37
 60        |                                                  0    19     0.00     70.37
 62        |                                                  0    19     0.00     70.37
 64        |***************                                   2    21     7.41     77.78
 66        |                                                  0    21     0.00     77.78
 68        |***************                                   2    23     7.41     85.19
 70        |***************                                   2    25     7.41     92.59
 72        |***************                                   2    27     7.41    100.00
 74        |                                                  0    27     0.00    100.00
 76        |                                                  0    27     0.00    100.00
 78        |                                                  0    27     0.00    100.00
 80        |                                                  0    27     0.00    100.00
            ----+---+---+---+---+---+---+---+---+-
                2   4   6   8  10  12  14  16  18

                        Percentage
```

Figure C7. Shell length (mm) frequency histogram of *Quadrula quadrula* in the UMR Mile 450.4 (Pool 17), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples

Shell Length		Freq	Cum Freq	Percent	Cum Percent
0		0	0	0.00	0.00
2		0	0	0.00	0.00
4		0	0	0.00	0.00
6		0	0	0.00	0.00
8		0	0	0.00	0.00
10		0	0	0.00	0.00
12		0	0	0.00	0.00
14		0	0	0.00	0.00
16		0	0	0.00	0.00
18		0	0	0.00	0.00
20		0	0	0.00	0.00
22		0	0	0.00	0.00
24		0	0	0.00	0.00
26		0	0	0.00	0.00
28		0	0	0.00	0.00
30		0	0	0.00	0.00
32		0	0	0.00	0.00
34		0	0	0.00	0.00
36		0	0	0.00	0.00
38		0	0	0.00	0.00
40		0	0	0.00	0.00
42		0	0	0.00	0.00
44	****	1	1	4.35	4.35
46	****	1	2	4.35	8.70
48	*********	2	4	8.70	17.39
50	****	1	5	4.35	21.74
52	*****************	4	9	17.39	39.13
54	**********************	5	14	21.74	60.87
56		0	14	0.00	60.87
58	*************	3	17	13.04	73.91
60	****	1	18	4.35	78.26
62	*************	3	21	13.04	91.30
64	****	1	22	4.35	95.65
66		0	22	0.00	95.65
68		0	22	0.00	95.65
70	****	1	23	4.35	100.00
72		0	23	0.00	100.00
74		0	23	0.00	100.00
76		0	23	0.00	100.00
78		0	23	0.00	100.00
80		0	23	0.00	100.00
82		0	23	0.00	100.00
84		0	23	0.00	100.00

```
-----+----+----+----+--
     5   10   15   20
```

Percentage

Figure C8. Shell length (mm) frequency histogram of *Quadrula metanevra* in the UMR Mile 450.4 (Pool 17), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples

```
Shell Length                                      Cum                 Cum
                                            Freq  Freq    Percent   Percent

     8   |**                                   2     2      0.94      0.94
    10   |**                                   2     4      0.94      1.88
    12   |*                                    1     5      0.47      2.35
    14   |**                                   2     7      0.94      3.29
    16   |******                               6    13      2.82      6.10
    18   |**********************              23    36     10.80     16.90
    20   |*********                           10    46      4.69     21.60
    22   |*********                           10    56      4.69     26.29
    24   |*****************                   18    74      8.45     34.74
    26   |*******************                 20    94      9.39     44.13
    28   |***********************             24   118     11.27     55.40
    30   |****                                 4   122      1.88     57.28
    32   |*****                                5   127      2.35     59.62
    34   |****                                 4   131      1.88     61.50
    36   |******                               6   137      2.82     64.32
    38   |*******                              7   144      3.29     67.61
    40   |*                                    1   145      0.47     68.08
    42   |*******                              7   152      3.29     71.36
    44   |********                             9   161      4.23     75.59
    46   |*****                                5   166      2.35     77.93
    48   |*******                              7   173      3.29     81.22
    50   |********                             9   182      4.23     85.45
    52   |*******                              7   189      3.29     88.73
    54   |****                                 4   193      1.88     90.61
    56   |*********                           10   203      4.69     95.31
    58   |*******                              7   210      3.29     98.59
    60   |***                                  3   213      1.41    100.00
    62   |                                     0   213      0.00    100.00
    64   |                                     0   213      0.00    100.00
    66   |                                     0   213      0.00    100.00
         ----+----+----+----+----+---
             2    4    6    8   10

              Percentage
```

Figure C9. Shell length (mm) frequency histogram of *Quadrula pustulosa* in the UMR Mile 450.4 (Pool 17), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples

```
Shell Length                                          Cum                 Cum
                                               Freq   Freq    Percent    Percent

     8  |                                         0      0      0.00       0.00
    10  |                                         0      0      0.00       0.00
    12  |                                         0      0      0.00       0.00
    14  |****                                     1      1      1.89       1.89
    16  |                                         0      1      0.00       1.89
    18  |                                         0      1      0.00       1.89
    20  |****                                     1      2      1.89       3.77
    22  |********                                 2      4      3.77       7.55
    24  |***********                              3      7      5.66      13.21
    26  |*******************                      5     12      9.43      22.64
    28  |**************************               7     19     13.21      35.85
    30  |******************************           8     27     15.09      50.94
    32  |***************                          4     31      7.55      58.49
    34  |*******************                      5     36      9.43      67.92
    36  |***************                          4     40      7.55      75.47
    38  |****                                     1     41      1.89      77.36
    40  |********                                 2     43      3.77      81.13
    42  |********                                 2     45      3.77      84.91
    44  |********                                 2     47      3.77      88.68
    46  |***************                          4     51      7.55      96.23
    48  |****                                     1     52      1.89      98.11
    50  |                                         0     52      0.00      98.11
    52  |****                                     1     53      1.89     100.00
    54  |                                         0     53      0.00     100.00
    56  |                                         0     53      0.00     100.00
    58  |                                         0     53      0.00     100.00
    60  |                                         0     53      0.00     100.00
        ----+---+---+---+---+---+---+--
            2   4   6   8  10  12  14

               Percentage
```

Figure C10. Shell length (mm) frequency histogram of *Obliquaria reflexa* in the UMR Mile 450.4 (Pool 17), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples

Shell Length		Freq	Cum Freq	Percent	Cum Percent
0		0	0	0.00	0.00
2		0	0	0.00	0.00
4		0	0	0.00	0.00
6		0	0	0.00	0.00
8		0	0	0.00	0.00
10		0	0	0.00	0.00
12	*	1	1	0.60	0.60
14	********	7	8	4.19	4.79
16	********************	17	25	10.18	14.97
18	****	3	28	1.80	16.77
20	****	3	31	1.80	18.56
22	******	5	36	2.99	21.56
24	******	5	41	2.99	24.55
26	********	7	48	4.19	28.74
28	*************	11	59	6.59	35.33
30	*****************	14	73	8.38	43.71
32	**********	8	81	4.79	48.50
34	********************	17	98	10.18	58.68
36	*****************	14	112	8.38	67.07
38	**********************	18	130	10.78	77.84
40	**********************	18	148	10.78	88.62
42	************	10	158	5.99	94.61
44	****	3	161	1.80	96.41
46	*****	4	165	2.40	98.80
48	*	1	166	0.60	99.40
50	*	1	167	0.60	100.00
52		0	167	0.00	100.00
54		0	167	0.00	100.00
	2 4 6 8 10				
	Percentage				

Figure C11. Shell length (mm) frequency histogram of *Truncilla truncata* in the UMR Mile 450.4 (Pool 17), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples

```
Shell Length                                        Cum                  Cum
                                              Freq  Freq     Percent   Percent
             |
   4         |                                  0     0        0.00      0.00
   6         |                                  0     0        0.00      0.00
   8         |                                  0     0        0.00      0.00
  10         |***                               1     1        3.33      3.33
  12         |                                  0     1        0.00      3.33
  14         |                                  0     1        0.00      3.33
  16         |*****************                 5     6       16.67     20.00
  18         |***************************       8    14       26.67     46.67
  20         |*****************                 5    19       16.67     63.33
  22         |******************************    9    28       30.00     93.33
  24         |*******                           2    30        6.67    100.00
  26         |                                  0    30        0.00    100.00
  28         |                                  0    30        0.00    100.00
  30         |                                  0    30        0.00    100.00
  32         |                                  0    30        0.00    100.00
             -----+----+----+----+----+----+
                  5   10   15   20   25   30

                     Percentage
```

Figure C12. Shell length (mm) frequency histogram of *Truncilla donaciformis* in the UMR Mile 450.4 (Pool 17), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples

```
Shell Length                                                        Cum                  Cum
                                                             Freq   Freq   Percent    Percent

     18  |                                                      0      0     0.00       0.00
     20  |*************                                         1      1     2.56       2.56
     22  |*************                                         1      2     2.56       5.13
     24  |                                                      0      2     0.00       5.13
     26  |                                                      0      2     0.00       5.13
     28  |                                                      0      2     0.00       5.13
     30  |                                                      0      2     0.00       5.13
     32  |                                                      0      2     0.00       5.13
     34  |                                                      0      2     0.00       5.13
     36  |                                                      0      2     0.00       5.13
     38  |                                                      0      2     0.00       5.13
     40  |                                                      0      2     0.00       5.13
     42  |                                                      0      2     0.00       5.13
     44  |                                                      0      2     0.00       5.13
     46  |                                                      0      2     0.00       5.13
     48  |                                                      0      2     0.00       5.13
     50  |                                                      0      2     0.00       5.13
     52  |                                                      0      2     0.00       5.13
     54  |                                                      0      2     0.00       5.13
     56  |                                                      0      2     0.00       5.13
     58  |                                                      0      2     0.00       5.13
     60  |                                                      0      2     0.00       5.13
     62  |                                                      0      2     0.00       5.13
     64  |                                                      0      2     0.00       5.13
     66  |                                                      0      2     0.00       5.13
     68  |*************                                         1      3     2.56       7.69
     70  |*************                                         1      4     2.56      10.26
     72  |                                                      0      4     0.00      10.26
     74  |                                                      0      4     0.00      10.26
     76  |                                                      0      4     0.00      10.26
     78  |                                                      0      4     0.00      10.26
     80  |                                                      0      4     0.00      10.26
     82  |*************                                         1      5     2.56      12.82
     84  |                                                      0      5     0.00      12.82
     86  |                                                      0      5     0.00      12.82
     88  |**************************                            2      7     5.13      17.95
     90  |**************************                            2      9     5.13      23.08
     92  |*************                                         1     10     2.56      25.64
     94  |*************                                         1     11     2.56      28.21
     96  |***************************************               3     14     7.69      35.90
     98  |*************                                         1     15     2.56      38.46
    100  |                                                      0     15     0.00      38.46
    102  |**************************                            2     17     5.13      43.59
    104  |**************************                            2     19     5.13      48.72
    106  |**************************                            2     21     5.13      53.85
    108  |                                                      0     21     0.00      53.85
    110  |                                                      0     21     0.00      53.85
    112  |                                                      0     21     0.00      53.85
    114  |*************                                         1     22     2.56      56.41
    116  |***************************************               3     25     7.69      64.10
    118  |*************                                         1     26     2.56      66.67
    120  |*************                                         1     27     2.56      69.23
    122  |**************************                            2     29     5.13      74.36
    124  |*************                                         1     30     2.56      76.92
    126  |*************                                         1     31     2.56      79.49
    128  |**************************                            2     33     5.13      84.62
    130  |                                                      0     33     0.00      84.62
    132  |*************                                         1     34     2.56      87.18
    134  |                                                      0     34     0.00      87.18
    136  |*************                                         1     35     2.56      89.74
    138  |*************                                         1     36     2.56      92.31
    140  |                                                      0     36     0.00      92.31
    142  |*************                                         1     37     2.56      94.87
    144  |                                                      0     37     0.00      94.87
    146  |*************                                         1     38     2.56      97.44
    148  |                                                      0     38     0.00      97.44
    150  |                                                      0     38     0.00      97.44
    152  |                                                      0     38     0.00      97.44
    154  |*************                                         1     39     2.56     100.00
    156  |                                                      0     39     0.00     100.00
    158  |                                                      0     39     0.00     100.00

          -----+----+----+----+----+----+----+---
               1    2    3    4    5    6    7

                        Percentage
```

Figure C13. Shell length (mm) frequency histogram of *Megalonaias nervosa* in the UMR Mile 504.8 (Pool 14), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

```
                                                   Cum               Cum
Shell Length                              Freq    Freq   Percent   Percent

   8 |                                       0       0     0.00      0.00
  10 |                                       0       0     0.00      0.00
  12 |***                                    1       1     0.68      0.68
  14 |                                       0       1     0.00      0.68
  16 |                                       0       1     0.00      0.68
  18 |*******                                2       3     1.37      2.05
  20 |*******                                2       5     1.37      3.42
  22 |**************                         4       9     2.74      6.16
  24 |*****************                      5      14     3.42      9.59
  26 |                                       0      14     0.00      9.59
  28 |**********                             3      17     2.05     11.64
  30 |*******                                2      19     1.37     13.01
  32 |***                                    1      20     0.68     13.70
  34 |*******                                2      22     1.37     15.07
  36 |***                                    1      23     0.68     15.75
  38 |***                                    1      24     0.68     16.44
  40 |************************               7      31     4.79     21.23
  42 |***                                    1      32     0.68     21.92
  44 |**************                         4      36     2.74     24.66
  46 |*******                                2      38     1.37     26.03
  48 |*****************                      5      43     3.42     29.45
  50 |*****************                      5      48     3.42     32.88
  52 |**********                             3      51     2.05     34.93
  54 |*******                                2      53     1.37     36.30
  56 |*******                                2      55     1.37     37.67
  58 |**********                             3      58     2.05     39.73
  60 |***                                    1      59     0.68     40.41
  62 |***                                    1      60     0.68     41.10
  64 |*****************                      5      65     3.42     44.52
  66 |*******                                2      67     1.37     45.89
  68 |*****************                      5      72     3.42     49.32
  70 |*******                                2      74     1.37     50.68
  72 |***                                    1      75     0.68     51.37
  74 |********************************** 10      85     6.85     58.22
  76 |********************************** 10      95     6.85     65.07
  78 |**************                         4      99     2.74     67.81
  80 |************************               7     106     4.79     72.60
  82 |*****************                      5     111     3.42     76.03
  84 |**************                         4     115     2.74     78.77
  86 |*********************                  6     121     4.11     82.88
  88 |*****************                      5     126     3.42     86.30
  90 |*****************                      5     131     3.42     89.73
  92 |************************               7     138     4.79     94.52
  94 |*******                                2     140     1.37     95.89
  96 |*******                                2     142     1.37     97.26
  98 |***                                    1     143     0.68     97.95
 100 |                                       0     143     0.00     97.95
 102 |**********                             3     146     2.05    100.00
 104 |                                       0     146     0.00    100.00
 106 |                                       0     146     0.00    100.00
      -----+----+----+----+----+----+----
           1    2    3    4    5    6

              Percentage
```

Figure C14. Shell length (mm) frequency histogram of *Amblema plicata plicata* in the UMR Mile 504.8 (Pool 14), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

```
                                                         Cum              Cum
Shell Length                                      Freq   Freq   Percent   Percent

    12  |                                           0      0      0.00      0.00
    14  |                                           0      0      0.00      0.00
    16  |                                           0      0      0.00      0.00
    18  |*****                                      1      1      2.44      2.44
    20  |***************                            3      4      7.32      9.76
    22  |*****                                      1      5      2.44     12.20
    24  |*****                                      1      6      2.44     14.63
    26  |                                           0      6      0.00     14.63
    28  |                                           0      6      0.00     14.63
    30  |                                           0      6      0.00     14.63
    32  |                                           0      6      0.00     14.63
    34  |                                           0      6      0.00     14.63
    36  |                                           0      6      0.00     14.63
    38  |**********                                 2      8      4.88     19.51
    40  |*****                                      1      9      2.44     21.95
    42  |**********                                 2     11      4.88     26.83
    44  |***************                            3     14      7.32     34.15
    46  |                                           0     14      0.00     34.15
    48  |*****                                      1     15      2.44     36.59
    50  |******************************             6     21     14.63     51.22
    52  |*****                                      1     22      2.44     53.66
    54  |***************                            3     25      7.32     60.98
    56  |***************                            3     28      7.32     68.29
    58  |*****                                      1     29      2.44     70.73
    60  |***************                            3     32      7.32     78.05
    62  |**********                                 2     34      4.88     82.93
    64  |***************                            3     37      7.32     90.24
    66  |                                           0     37      0.00     90.24
    68  |*****                                      1     38      2.44     92.68
    70  |                                           0     38      0.00     92.68
    72  |**********                                 2     40      4.88     97.56
    74  |                                           0     40      0.00     97.56
    76  |                                           0     40      0.00     97.56
    78  |*****                                      1     41      2.44    100.00
    80  |                                           0     41      0.00    100.00
    82  |                                           0     41      0.00    100.00
         ----+----+----+----+----+----+----+-
             2    4    6    8   10   12   14

                  Percentage
```

Figure C15. Shell length (mm) frequency histogram of *Ellipsaria lineolata* in the UMR Mile 504.8 (Pool 14), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

Shell Length		Freq	Cum Freq	Percent	Cum Percent
10		0	0	0.00	0.00
12	******	1	1	1.52	1.52
14		0	1	0.00	1.52
16		0	1	0.00	1.52
18	******	1	2	1.52	3.03
20		0	2	0.00	3.03
22	******	1	3	1.52	4.55
24		0	3	0.00	4.55
26		0	3	0.00	4.55
28		0	3	0.00	4.55
30		0	3	0.00	4.55
32		0	3	0.00	4.55
34	************	2	5	3.03	7.58
36		0	5	0.00	7.58
38	******	1	6	1.52	9.09
40		0	6	0.00	9.09
42	******	1	7	1.52	10.61
44	******	1	8	1.52	12.12
46		0	8	0.00	12.12
48	******	1	9	1.52	13.64
50	************	2	11	3.03	16.67
52	************************************	6	17	9.09	25.76
54	************************	4	21	6.06	31.82
56	******************	3	24	4.55	36.36
58	************************	4	28	6.06	42.42
60	************************	4	32	6.06	48.48
62	************************	4	36	6.06	54.55
64	******************	3	39	4.55	59.09
66	******************	3	42	4.55	63.64
68	************************************	6	48	9.09	72.73
70	******************	3	51	4.55	77.27
72	******************************	5	56	7.58	84.85
74	******	1	57	1.52	86.36
76	******************	3	60	4.55	90.91
78	******************	3	63	4.55	95.45
80		0	63	0.00	95.45
82	************	2	65	3.03	98.48
84	******	1	66	1.52	100.00
86		0	66	0.00	100.00
88		0	66	0.00	100.00
90		0	66	0.00	100.00
	1 2 3 4 5 6 7 8 9				
	Percentage				

Figure C16. Shell length (mm) frequency histogram of *Quadrula quadrula* in the UMR Mile 504.8 (Pool 14), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

```
Shell Length                                         Cum               Cum
                                               Freq  Freq   Percent   Percent

      8  |                                        0     0     0.00      0.00
     10  |******                                  3     3     2.86      2.86
     12  |                                        0     3     0.00      2.86
     14  |**                                      1     4     0.95      3.81
     16  |********                                4     8     3.81      7.62
     18  |******                                  3    11     2.86     10.48
     20  |****                                    2    13     1.90     12.38
     22  |**                                      1    14     0.95     13.33
     24  |******                                  3    17     2.86     16.19
     26  |**                                      1    18     0.95     17.14
     28  |                                        0    18     0.00     17.14
     30  |                                        0    18     0.00     17.14
     32  |**                                      1    19     0.95     18.10
     34  |************                            6    25     5.71     23.81
     36  |********                                4    29     3.81     27.62
     38  |****                                    2    31     1.90     29.52
     40  |******                                  3    34     2.86     32.38
     42  |**********                              5    39     4.76     37.14
     44  |**************                          7    46     6.67     43.81
     46  |**************************             13    59    12.38     56.19
     48  |************************               12    71    11.43     67.62
     50  |************                            6    77     5.71     73.33
     52  |****************                        8    85     7.62     80.95
     54  |**********                              5    90     4.76     85.71
     56  |**************                          7    97     6.67     92.38
     58  |**********                              5   102     4.76     97.14
     60  |                                        0   102     0.00     97.14
     62  |**                                      1   103     0.95     98.10
     64  |**                                      1   104     0.95     99.05
     66  |**                                      1   105     0.95    100.00
     68  |                                        0   105     0.00    100.00
     70  |                                        0   105     0.00    100.00
         ----+---+---+---+---+---+-
             2   4   6   8   10  12

               Percentage
```

Figure C17. Shell length (mm) frequency histogram of *Quadrula pustulosa* in the UMR Mile 504.8 (Pool 14), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

```
 Shell Length                                                      Cum               Cum
                                                            Freq   Freq   Percent   Percent

      12  |                                                    0      0      0.00      0.00
      14  |                                                    0      0      0.00      0.00
      16  |                                                    0      0      0.00      0.00
      18  |******                                              1      1      2.94      2.94
      20  |************                                        2      3      5.88      8.82
      22  |******                                              1      4      2.94     11.76
      24  |                                                    0      4      0.00     11.76
      26  |                                                    0      4      0.00     11.76
      28  |                                                    0      4      0.00     11.76
      30  |                                                    0      4      0.00     11.76
      32  |                                                    0      4      0.00     11.76
      34  |                                                    0      4      0.00     11.76
      36  |                                                    0      4      0.00     11.76
      38  |                                                    0      4      0.00     11.76
      40  |                                                    0      4      0.00     11.76
      42  |******                                              1      5      2.94     14.71
      44  |************                                        2      7      5.88     20.59
      46  |******                                              1      8      2.94     23.53
      48  |************************                            4     12     11.76     35.29
      50  |******************                                  3     15      8.82     44.12
      52  |******************                                  3     18      8.82     52.94
      54  |************************************                6     24     17.65     70.59
      56  |******************                                  3     27      8.82     79.41
      58  |******************                                  3     30      8.82     88.24
      60  |                                                    0     30      0.00     88.24
      62  |************                                        2     32      5.88     94.12
      64  |                                                    0     32      0.00     94.12
      66  |******                                              1     33      2.94     97.06
      68  |                                                    0     33      0.00     97.06
      70  |******                                              1     34      2.94    100.00
      72  |                                                    0     34      0.00    100.00
      74  |                                                    0     34      0.00    100.00
          ----+---+---+---+---+---+---+---+---
              2   4   6   8  10  12  14  16

                    Percentage
```

Figure C18. Shell length (mm) frequency histogram of *Obovaria olivaria* in the UMR Mile 504.8 (Pool 14), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

```
Shell Length                                                      Cum              Cum
                                                           Freq   Freq   Percent   Percent

   10  |                                                      0      0      0.00      0.00
   12  |**                                                    1      1      0.89      0.89
   14  |                                                      0      1      0.00      0.89
   16  |                                                      0      1      0.00      0.89
   18  |                                                      0      1      0.00      0.89
   20  |**                                                    1      2      0.89      1.79
   22  |**                                                    1      3      0.89      2.68
   24  |*****                                                 3      6      2.68      5.36
   26  |**                                                    1      7      0.89      6.25
   28  |*************                                         7     14      6.25     12.50
   30  |****                                                  2     16      1.79     14.29
   32  |*****                                                 3     19      2.68     16.96
   34  |*****                                                 3     22      2.68     19.64
   36  |**************                                        8     30      7.14     26.79
   38  |*************                                         7     37      6.25     33.04
   40  |*************************                            14     51     12.50     45.54
   42  |************************************                 20     71     17.86     63.39
   44  |********************************                     18     89     16.07     79.46
   46  |****************                                      9     98      8.04     87.50
   48  |****************                                      9    107      8.04     95.54
   50  |*****                                                 3    110      2.68     98.21
   52  |****                                                  2    112      1.79    100.00
   54  |                                                      0    112      0.00    100.00
   56  |                                                      0    112      0.00    100.00
   58  |                                                      0    112      0.00    100.00
   60  |                                                      0    112      0.00    100.00
        ----+---+---+---+---+---+---+---+---+
            2   4   6   8  10  12  14  16  18

                  Percentage
```

Figure C19. Shell length (mm) frequency histogram of *Obliquaria reflexa* in the UMR Mile 504.8 (Pool 14), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

```
Shell Length                                                    Cum              Cum
                                                         Freq   Freq   Percent   Percent

     6  |                                                   0      0     0.00      0.00
     8  |                                                   0      0     0.00      0.00
    10  |*                                                  1      1     0.67      0.67
    12  |***                                                2      3     1.34      2.01
    14  |****                                               3      6     2.01      4.03
    16  |********                                           6     12     4.03      8.05
    18  |***                                                2     14     1.34      9.40
    20  |****                                               3     17     2.01     11.41
    22  |                                                   0     17     0.00     11.41
    24  |*******                                            5     22     3.36     14.77
    26  |*********                                          7     29     4.70     19.46
    28  |********                                           6     35     4.03     23.49
    30  |********                                           6     41     4.03     27.52
    32  |********                                           6     47     4.03     31.54
    34  |****************                                  12     59     8.05     39.60
    36  |******************************                    22     81    14.77     54.36
    38  |***********************                           17     98    11.41     65.77
    40  |*******************                               14    112     9.40     75.17
    42  |****************************                      21    133    14.09     89.26
    44  |***************                                   11    144     7.38     96.64
    46  |*******                                            5    149     3.36    100.00
    48  |                                                   0    149     0.00    100.00
    50  |                                                   0    149     0.00    100.00
    52  |                                                   0    149     0.00    100.00
        ----+---+---+---+---+---+---+--
            2   4   6   8   10  12  14

                 Percentage
```

Figure C20. Shell length (mm) frequency histogram of *Truncilla truncata* in the UMR Mile 504.8 (Pool 14), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

```
Shell Length                                      Cum                Cum
                                            Freq  Freq    Percent   Percent
        |
    0   |                                     0     0      0.00      0.00
    2   |                                     0     0      0.00      0.00
    4   |                                     0     0      0.00      0.00
    6   |                                     0     0      0.00      0.00
    8   |                                     0     0      0.00      0.00
   10   |                                     0     0      0.00      0.00
   12   |                                     0     0      0.00      0.00
   14   |******************                   7     7      3.57      3.57
   16   |**********                           4    11      2.04      5.61
   18   |********                             3    14      1.53      7.14
   20   |*************                        5    19      2.55      9.69
   22   |**********                           4    23      2.04     11.73
   24   |*******************************      12    35      6.12     17.86
   26   |********************                 8    43      4.08     21.94
   28   |*************                        5    48      2.55     24.49
   30   |*************                        5    53      2.55     27.04
   32   |**********                           4    57      2.04     29.08
   34   |******************                   7    64      3.57     32.65
   36   |**********                           4    68      2.04     34.69
   38   |***************                      6    74      3.06     37.76
   40   |**********                           4    78      2.04     39.80
   42   |******************                   7    85      3.57     43.37
   44   |**********                           4    89      2.04     45.41
   46   |***************                      6    95      3.06     48.47
   48   |*************                        5   100      2.55     51.02
   50   |*************                        5   105      2.55     53.57
   52   |**********                           4   109      2.04     55.61
   54   |********                             3   112      1.53     57.14
   56   |*****                                2   114      1.02     58.16
   58   |******************                   7   121      3.57     61.73
   60   |***************                      6   127      3.06     64.80
   62   |******************                   7   134      3.57     68.37
   64   |**************************          10   144      5.10     73.47
   66   |***********************              9   153      4.59     78.06
   68   |***************                      6   159      3.06     81.12
   70   |***************                      6   165      3.06     84.18
   72   |******************                   7   172      3.57     87.76
   74   |********                             3   175      1.53     89.29
   76   |********                             3   178      1.53     90.82
   78   |********                             3   181      1.53     92.35
   80   |*****                                2   183      1.02     93.37
   82   |*****                                2   185      1.02     94.39
   84   |***                                  1   186      0.51     94.90
   86   |***                                  1   187      0.51     95.41
   88   |********                             3   190      1.53     96.94
   90   |***                                  1   191      0.51     97.45
   92   |                                     0   191      0.00     97.45
   94   |********                             3   194      1.53     98.98
   96   |                                     0   194      0.00     98.98
   98   |***                                  1   195      0.51     99.49
  100   |***                                  1   196      0.51    100.00
  102   |                                     0   196      0.00    100.00
  104   |                                     0   196      0.00    100.00
  106   |                                     0   196      0.00    100.00
        -----+----+----+----+----+----+-
             1    2    3    4    5    6

                 Percentage
```

Figure C21. Shell length (mm) frequency histogram of *Amblema plicata plicata* in the UMR Mile 571.5 (Pool 12), nearshore, midshore, and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples (20 at each site)

Shell Length		Freq	Cum Freq	Percent	Cum Percent
0		0	0	0.00	0.00
2		0	0	0.00	0.00
4		0	0	0.00	0.00
6		0	0	0.00	0.00
8		0	0	0.00	0.00
10	******	1	1	2.78	2.78
12	******	1	2	2.78	5.56
14		0	2	0.00	5.56
16		0	2	0.00	5.56
18		0	2	0.00	5.56
20		0	2	0.00	5.56
22		0	2	0.00	5.56
24		0	2	0.00	5.56
26		0	2	0.00	5.56
28	******	1	3	2.78	8.33
30		0	3	0.00	8.33
32	***********	2	5	5.56	13.89
34	***********	2	7	5.56	19.44
36	******	1	8	2.78	22.22
38		0	8	0.00	22.22
40		0	8	0.00	22.22
42		0	8	0.00	22.22
44		0	8	0.00	22.22
46		0	8	0.00	22.22
48	******	1	9	2.78	25.00
50		0	9	0.00	25.00
52	***********	2	11	5.56	30.56
54	***********	2	13	5.56	36.11
56	****************************	5	18	13.89	50.00
58	***********	2	20	5.56	55.56
60	***********	2	22	5.56	61.11
62	***********	2	24	5.56	66.67
64	**********************	4	28	11.11	77.78
66	***********	2	30	5.56	83.33
68	***********	2	32	5.56	88.89
70		0	32	0.00	88.89
72		0	32	0.00	88.89
74		0	32	0.00	88.89
76	***********	2	34	5.56	94.44
78		0	34	0.00	94.44
80		0	34	0.00	94.44
82	******	1	35	2.78	97.22
84	******	1	36	2.78	100.00
86		0	36	0.00	100.00
88		0	36	0.00	100.00
90		0	36	0.00	100.00
92		0	36	0.00	100.00

```
----+---+---+---+---+---+---+
    2   4   6   8  10  12  14
```

Percentage

Figure C22. Shell length (mm) frequency histogram of *Quadrula quadrula* in the UMR Mile 571.5 (Pool 12), nearshore, midshore, and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples (20 at each site)

```
Shell Length                                          Cum               Cum
                                                Freq  Freq   Percent   Percent

   12   |                                          0     0      0.00      0.00
   14   |                                          0     0      0.00      0.00
   16   |                                          0     0      0.00      0.00
   18   |**                                        1     1      1.03      1.03
   20   |**                                        1     2      1.03      2.06
   22   |                                          0     2      0.00      2.06
   24   |                                          0     2      0.00      2.06
   26   |******                                    3     5      3.09      5.15
   28   |************************                 12    17     12.37     17.53
   30   |************                              6    23      6.19     23.71
   32   |**************                            7    30      7.22     30.93
   34   |**********************                   11    41     11.34     42.27
   36   |******************                        9    50      9.28     51.55
   38   |******************************           15    65     15.46     67.01
   40   |****************************             14    79     14.43     81.44
   42   |**************                            7    86      7.22     88.66
   44   |**************                            7    93      7.22     95.88
   46   |********                                  4    97      4.12    100.00
   48   |                                          0    97      0.00    100.00
   50   |                                          0    97      0.00    100.00
   52   |                                          0    97      0.00    100.00
        ----+---+---+---+---+---+---+---
            2   4   6   8  10  12  14

                  Percentage
```

Figure C23. Shell length (mm) frequency histogram of *Obliquaria reflexa* in the UMR Mile 571.5 (Pool 12), nearshore, midshore, and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples (20 at each site)

Shell Length		Freq	Cum Freq	Percent	Cum Percent
8		0	0	0.00	0.00
10		0	0	0.00	0.00
12		0	0	0.00	0.00
14	*********	4	4	4.30	4.30
16	**	1	5	1.08	5.38
18	**	1	6	1.08	6.45
20	****	2	8	2.15	8.60
22	*********	4	12	4.30	12.90
24	************************	11	23	11.83	24.73
26	*************	6	29	6.45	31.18
28	******************************	14	43	15.05	46.24
30	*****************	8	51	8.60	54.84
32	*******************	9	60	9.68	64.52
34	***************	7	67	7.53	72.04
36	******	3	70	3.23	75.27
38	*************	6	76	6.45	81.72
40	*************	6	82	6.45	88.17
42	***********	5	87	5.38	93.55
44	*********	4	91	4.30	97.85
46	****	2	93	2.15	100.00
48		0	93	0.00	100.00
50		0	93	0.00	100.00
52		0	93	0.00	100.00
	2 4 6 8 10 12 14				
	Percentage				

Figure C24. Shell length (mm) frequency histogram of *Truncilla truncata* in the UMR Mile 571.5 (Pool 12), nearshore, midshore, and farshore sites combined, July 1992. Organisms were obtained by having divers collect 60 quantitative (0.25-sq m quadrat) samples (20 at each site)

```
Shell Length                                                      Cum               Cum
                                                            Freq  Freq   Percent   Percent

  52 |                                                         0     0     0.00      0.00
  54 |                                                         0     0     0.00      0.00
  56 |                                                         0     0     0.00      0.00
  58 |************                                             1     1     3.03      3.03
  60 |                                                         0     1     0.00      3.03
  62 |                                                         0     1     0.00      3.03
  64 |************                                             1     2     3.03      6.06
  66 |                                                         0     2     0.00      6.06
  68 |                                                         0     2     0.00      6.06
  70 |                                                         0     2     0.00      6.06
  72 |                                                         0     2     0.00      6.06
  74 |                                                         0     2     0.00      6.06
  76 |************                                             1     3     3.03      9.09
  78 |************************                                 2     5     6.06     15.15
  80 |                                                         0     5     0.00     15.15
  82 |************                                             1     6     3.03     18.18
  84 |                                                         0     6     0.00     18.18
  86 |************************                                 2     8     6.06     24.24
  88 |************                                             1     9     3.03     27.27
  90 |************************                                 2    11     6.06     33.33
  92 |************                                             1    12     3.03     36.36
  94 |                                                         0    12     0.00     36.36
  96 |************************                                 2    14     6.06     42.42
  98 |************                                             1    15     3.03     45.45
 100 |************                                             1    16     3.03     48.48
 102 |************************                                 2    18     6.06     54.55
 104 |************************************                     3    21     9.09     63.64
 106 |************                                             1    22     3.03     66.67
 108 |************                                             1    23     3.03     69.70
 110 |************************************                     3    26     9.09     78.79
 112 |                                                         0    26     0.00     78.79
 114 |************************                                 2    28     6.06     84.85
 116 |                                                         0    28     0.00     84.85
 118 |                                                         0    28     0.00     84.85
 120 |                                                         0    28     0.00     84.85
 122 |************                                             1    29     3.03     87.88
 124 |************                                             1    30     3.03     90.91
 126 |                                                         0    30     0.00     90.91
 128 |                                                         0    30     0.00     90.91
 130 |                                                         0    30     0.00     90.91
 132 |                                                         0    30     0.00     90.91
 134 |************                                             1    31     3.03     93.94
 136 |                                                         0    31     0.00     93.94
 138 |                                                         0    31     0.00     93.94
 140 |************                                             1    32     3.03     96.97
 142 |                                                         0    32     0.00     96.97
 144 |                                                         0    32     0.00     96.97
 146 |************                                             1    33     3.03    100.00
 148 |                                                         0    33     0.00    100.00
 150 |                                                         0    33     0.00    100.00
 152 |                                                         0    33     0.00    100.00
     ----+---+---+---+---+---+---+---+---+
         1   2   3   4   5   6   7   8   9

              Percentage
```

Figure C25. Shell length (mm) frequency histogram of *Megalonaias nervosa* in the UMR Mile 635.2 (Pool 10), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

Shell Length		Freq	Cum Freq	Percent	Cum Percent
12		0	0	0.00	0.00
14	*	1	1	0.27	0.27
16	**************	10	11	2.71	2.98
18	***	2	13	0.54	3.52
20	*****	4	17	1.08	4.61
22	************************	18	35	4.88	9.49
24	***************************	20	55	5.42	14.91
26	****************	12	67	3.25	18.16
28	***************	11	78	2.98	21.14
30	***************	11	89	2.98	24.12
32	********	6	95	1.63	25.75
34	*****	4	99	1.08	26.83
36	*****	4	103	1.08	27.91
38	********	6	109	1.63	29.54
40	***********	8	117	2.17	31.71
42	**************	10	127	2.71	34.42
44	*****	4	131	1.08	35.50
46	***	2	133	0.54	36.04
48	*****	4	137	1.08	37.13
50	*****	4	141	1.08	38.21
52	****	3	144	0.81	39.02
54		0	144	0.00	39.02
56	**************	10	154	2.71	41.73
58	*****	4	158	1.08	42.82
60	*******	5	163	1.36	44.17
62	******************	13	176	3.52	47.70
64	**************	10	186	2.71	50.41
66	*******************	14	200	3.79	54.20
68	***************	11	211	2.98	57.18
70	***********************	17	228	4.61	61.79
72	*******************	14	242	3.79	65.58
74	************************	18	260	4.88	70.46
76	******************	13	273	3.52	73.98
78	******************************	22	295	5.96	79.95
80	***********************	17	312	4.61	84.55
82	************	9	321	2.44	86.99
84	************	9	330	2.44	89.43
86	********	6	336	1.63	91.06
88	******************	13	349	3.52	94.58
90	********	6	355	1.63	96.21
92	************	9	36[illegible]	2.44	98.64
94	*******	5	36[illegible]	1.36	100.00
96		0	369	0.00	100.00
98		0	369	0.00	100.00
100		0	369	0.00	100.00

```
-----+----+----+----+----+----+
     1    2    3    4    5    6
```

Percentage

Figure C26. Shell length (mm) frequency histogram of *Amblema plicata plicata* in the UMR Mile 635.2 (Pool 10), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

```
                                                         Cum              Cum
Shell Length                                     Freq    Freq   Percent   Percent

  8  |                                              0       0     0.00      0.00
 10  |                                              0       0     0.00      0.00
 12  |                                              0       0     0.00      0.00
 14  |*****************                             1       1     4.35      4.35
 16  |                                              0       1     0.00      4.35
 18  |                                              0       1     0.00      4.35
 20  |                                              0       1     0.00      4.35
 22  |*****************                             1       2     4.35      8.70
 24  |                                              0       2     0.00      8.70
 26  |                                              0       2     0.00      8.70
 28  |                                              0       2     0.00      8.70
 30  |                                              0       2     0.00      8.70
 32  |***********************************           2       4     8.70     17.39
 34  |***********************************           2       6     8.70     26.09
 36  |***********************************           2       8     8.70     34.78
 38  |*****************                             1       9     4.35     39.13
 40  |                                              0       9     0.00     39.13
 42  |                                              0       9     0.00     39.13
 44  |*****************                             1      10     4.35     43.48
 46  |***********************************           2      12     8.70     52.17
 48  |***********************************           2      14     8.70     60.87
 50  |*****************                             1      15     4.35     65.22
 52  |*****************                             1      16     4.35     69.57
 54  |                                              0      16     0.00     69.57
 56  |*****************                             1      17     4.35     73.91
 58  |                                              0      17     0.00     73.91
 60  |                                              0      17     0.00     73.91
 62  |*****************                             1      18     4.35     78.26
 64  |*****************                             1      19     4.35     82.61
 66  |*****************                             1      20     4.35     86.96
 68  |                                              0      20     0.00     86.96
 70  |*****************                             1      21     4.35     91.30
 72  |                                              0      21     0.00     91.30
 74  |*****************                             1      22     4.35     95.65
 76  |                                              0      22     0.00     95.65
 78  |*****************                             1      23     4.35    100.00
 80  |                                              0      23     0.00    100.00
 82  |                                              0      23     0.00    100.00
 84  |                                              0      23     0.00    100.00
     ----+----+----+----+----+----+----+----+---
         1    2    3    4    5    6    7    8

              Percentage
```

Figure C27. Shell length (mm) frequency histogram of *Fusconaia flava* in the UMR Mile 635.2 (Pool 10), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

```
Shell Length                                         Cum               Cum
                                               Freq  Freq   Percent   Percent

   14   |                                        0     0     0.00      0.00
   16   |                                        0     0     0.00      0.00
   18   |                                        0     0     0.00      0.00
   20   |*************                           2     2     6.67      6.67
   22   |*******                                 1     3     3.33     10.00
   24   |*******                                 1     4     3.33     13.33
   26   |                                        0     4     0.00     13.33
   28   |***************************             4     8    13.33     26.67
   30   |*******                                 1     9     3.33     30.00
   32   |*************                           2    11     6.67     36.67
   34   |*************                           2    13     6.67     43.33
   36   |*******                                 1    14     3.33     46.67
   38   |*************                           2    16     6.67     53.33
   40   |********************                    3    19    10.00     63.33
   42   |********************                    3    22    10.00     73.33
   44   |********************                    3    25    10.00     83.33
   46   |                                        0    25     0.00     83.33
   48   |*************                           2    27     6.67     90.00
   50   |*************                           2    29     6.67     96.67
   52   |                                        0    29     0.00     96.67
   54   |                                        0    29     0.00     96.67
   56   |*******                                 1    30     3.33    100.00
   58   |                                        0    30     0.00    100.00
   60   |                                        0    30     0.00    100.00
         ---+---+---+---+---+---+---
            2   4   6   8  10  12

              Percentage
```

Figure C28. Shell length (mm) frequency histogram of *Obliquaria reflexa* in the UMR Mile 635.2 (Pool 10), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

Shell Length		Freq	Cum Freq	Percent	Cum Percent
6		0	0	0.00	0.00
8		0	0	0.00	0.00
10		0	0	0.00	0.00
12	**	1	1	0.86	0.86
14	*****	3	4	2.59	3.45
16	***	2	6	1.72	5.17
18		0	6	0.00	5.17
20	**	1	7	0.86	6.03
22	***	2	9	1.72	7.76
24	*******	4	13	3.45	11.21
26	**************	8	21	6.90	18.10
28	************************	14	35	12.07	30.17
30	*********************	12	47	10.34	40.52
32	*********	5	52	4.31	44.83
34	*****************	10	62	8.62	53.45
36	****************	9	71	7.76	61.21
38	*********************	12	83	10.34	71.55
40	****************	9	92	7.76	79.31
42	****************	9	101	7.76	87.07
44	*****	3	104	2.59	89.66
46	*********	5	109	4.31	93.97
48	**	1	110	0.86	94.83
50	***	2	112	1.72	96.55
52	***	2	114	1.72	98.28
54	**	1	115	0.86	99.14
56	**	1	116	0.86	100.00
58		0	116	0.00	100.00
60		0	116	0.00	100.00
	2 4 6 8 10 12				
	Percentage				

Figure C29. Shell length (mm) frequency histogram of *Truncilla truncata* in the UMR Mile 635.2 (Pool 10), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-ℓ buckets of sediment (20 at a nearshore site and 20 at a farshore site)

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13. ABSTRACT *(Maximum 200 words)*

In 1988, the U.S. Army Engineer District, St. Louis, initiated a monitoring program to analyze the effects of commercial navigation traffic on freshwater mussels (Mollusca: Unionidae), especially the endangered *Lampsilis higginsi* in the upper Mississippi River. Preliminary studies were conducted in 1988; detailed studies were initiated in 1989 and will continue for at least 6 years. In July 1992, bivalves were collected using qualitative and quantitative (0.25-sq m total substrate) methods at dense and diverse beds at the following river miles: 299.6 (Pool 24), 450.4 (Pool 17), 504.8 (Pool 14), 571.5 (Pool 12), and 635.2 (Pool 10).

Although community composition varied among sites, the unionid fauna was dominated by *Amblema plicata plicata* which comprised nearly 40 percent of the fauna and was taken in 85 percent of the samples. At River Mile (RM) 450.4, the overall mean density ($\pm$ standard error of the mean, SE) at the nearshore site (76.4 $\pm$4.6 individuals/sq m) was significantly greater ($P < 0.05$) than at the farshore site (50.8 $\pm$5.7 individuals/sq m. At RM 572.5, mean mussel densities were not significantly different among sites ($P > 0.05$). Species diversity (H') ranged from slightly more than 1.5 to about 2.5 at all five mussel beds. Based on qualitative sampling methods, *L. higginsi* comprised 0.78 percent (three individuals) at RM 504.8 and 0.27 percent (1 individual) at RM 635.2.

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13. Concluded.

Based on studies conducted at RM 571.5, passage of commercial vessels appeared to have little or no effects on water turbidity (ambient turbidity ranged from approximately 38 to 90 NTU). Beds in Pools 17, 14, 12, and 10 all supported populations of *A. p. plicata* with relatively equal abundance of most size and age classes; the Pool 24 population was heavily dominated by a single year class (1988) of recruits.

Six attributes of mussel beds were examined to judge the health of these beds: (a) decrease in density of five common-to-abundant species, (b) presence of *L. higginsi* (if within its range), (c) live-to-recently-dead ratios for dominant species, (d) loss of more than 25 percent of the mussel species, (e) evidence of recent recruitment, and (f) a significant change in growth rates or mortality of dominant species. An examination of these six attributes, based on information collected to date, reveals that biotic conditions are stable at these beds.

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